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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2324

FATIGUE STRENGTHS OF AIRCRAFT MATERIALS

AXIAL-LOAD FATIGUE TESTS ON UNNOTCHED SHEET SPECIMENS OF 24S-T3 AND 75S-T6 ALUMINUM ALLOYS AND OF SAE 4130 STEEL

By H. J. Grover, S. M. Bishop, and L. R. Jackson

Battelle Memorial Institute

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NOTICE

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SUMMARY

This report presents information on the axial-load fatigue behavior of unnotched specimens of each of three sheet materials: 24S-T3 and 75S-T6 aluminum alloys and normalized SAE 4130 steel.

The experimental investigation of these materials included the following items:

1. Determination of fatigue strengths, in tests at a speed of about 1100 cycles per minute, covering a range of mean loads from zero to a high tensile value and, for each loading condition, lifetimes from 10,000 to 10,000,000 cycles

2. Determination of fatigue strengths in tests at a slower speed of about 90 cycles per minute

3. Several measurements of damage or strengthening at one stress level due to previous loading at another stress level; these tests included interchanging the order of application of high stress level and low stress level

In several respects, fatigue test data are extended beyond those previously available. However, results are in general agreement with such previously reported data as are available for comparison. The main observation unpredictable from previous work is that fatigue strengths at 90 cycles per minute appear, in some ranges of loading, appreciably lower (up to 10 percent) than corresponding strengths at 1100 cycles per minute.

INTRODUCTION

A wartime survey (reference 1) showed a lack of complete information on the fatigue properties of sheet materials used in airframe construction. Although a great deal of information was available, it appeared that no material had been investigated fully and that no strictly comparative tests of large extent had been made on different materials under carefully controlled conditions. Therefore, it was planned to investigate rather fully the fatigue behavior of each of three metals commonly used in airframe construction: 24S-T3 and 75S-T6 aluminum alloys and SAE 4130 steel. Each metal has been tested in one thickness (0.090 in. for the aluminum alloys and 0.075 in. for the steel), and all tests have been conducted under axial loading (of obvious importance in stressed-skin construction).

The results, of interest in themselves, also furnish basic information for further studies of the same materials. In view of this possibility, care has been taken to evaluate the experimental errors involved and to estimate, insofar as is possible, the residual "scatter" of test points.

This investigation was conducted at the Battelle Memorial Institute under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

Acknowledgment is due to Mr. David O. Leeser, who, while on the staff of Battelle Memorial Institute, contributed a major part of the experimental work described in this report. The authors would also like to express appreciation to Mr. Paul Kuhn, of the Structures Research Division of the Langley Aeronautical Laboratory of the NACA at Langley Field, Virginia, for many helpful discussions during the course of the investigation.

SHEET MATERIAL AND TEST SPECIMENS

Coupons cut from 135 sheets (0.090 in. thick) of each aluminum alloy and from 270 sheets (0.075 in. thick) of the steel were furnished by the NACA. Each sheet was laid out to provide four static tension blanks with the grain (rolling direction) and four static tension blanks across the grain, four static compression blanks with the grain and four static compression blanks across the grain, four fatigue test blanks with the grain, and a number of blanks for possible future use. As shown in figures 1 and 2, the layouts were such that a sample was taken from each section of each sheet for the various tests.

Test pieces were machined at Battelle from these coupons.

Static Test Specimens

Static tension test coupons were machined to conform with the A.S.T.M. standard for sheet metals (reference 2). The static compression test coupons were machined and ground 0.625 inch in width by 2.625 inches in length with ends parallel to each other and normal to the longitudinal or vertical axis of the specimen.

Fatigue Test Specimens

For fatigue test specimens, blanks of each material were cut approximately 3 by 18 inches with the grain running the long dimension of the blank. These were protected on each face with a zinc chromate primer. With this coating still on, each blank was machined to the shape shown in figure 3. Previous experience had shown this to be a desirable specimen for sheet fatigue tests (reference 3).

A reduction from a width of 1.000 to 0.800 inch in some of the steel specimens was necessitated by the load capacities of the available fatigue testing machines. Cross checks indicated that this decrease in width did not significantly affect test results.

Specimens were polished electrolytically (after preliminary tests to justify this procedure for the materials concerned; see appendix A).

TEST EQUIPMENT AND PROCEDURE

Static Tests

Tension tests were made in a Baldwin-Southwark universal testing machine with a Templin type recorder. Compression tests were made in the same machine with a Montgomery-Templin roller-type compression jig. Tests conducted at the Langley Aeronautical Laboratory showed that compression stress-strain curves obtained with the roller-type support were more accurate than curves obtained with other types of support available (reference 4).

Loading rate for the static tests was 0.03 inch per minute.

Fatigue Tests

All fatigue tests were run on Krouse direct repeated-stress testing machines (reference 3), one of which is shown in figure 4. These machines have a nominal capacity of 10,000 pounds tension to 10,000 pounds compression. When the machines were operated at the normal speed of about

1100 cycles per minute, the determination of fatigue strengths covered a range of mean loads from zero to a high tensile value and, for each loading condition, lifetimes from 10,000 to 10,000,000 cycles. A belt drive was arranged for the low-speed tests to give a speed of about 90 cycles per minute. The machines are of constant-deflection type; however, each is equipped with a sensitive means of detection of load decrease, so that tests can be generally considered as run at nearly constant load. Before this investigation was undertaken, the machines were recalibrated both statically and dynamically. The estimated precision of setting and maintaining loads was about ±3 percent for tension-tension tests and about ±5 percent for tension-compression tests.

Tension-tension tests were run with the self-alining type of grips used in previous investigations conducted at Battelle (reference 3). Measurements with bonded wire strain gages have shown that, with careful loading, the tension-tension grips have uniformity of stresses across the 1-inch gage length of a sheet specimen to about ±500 psi. The alinement of the grips in the testing machine keeps bending stresses below about 500 psi.

Tension-compression tests probably have somewhat less precision. Construction details of the tension-compression grips and guide plates are shown in figures 5 and 6. This general method was developed at the National Bureau of Standards (reference 5). There are two difficulties:

(1) If the guide plates are too tight and specimens are not perfectly flat, an appreciable, unmeasured fraction of the applied load goes into friction

(2) If the guide plates are too loose, the specimen buckles on the compression part of the cycle and bending stresses may become large

Experiments with bonded wire strain gages were performed to determine optimum conditions for using the guide plates. These experiments are described in appendix B; it appeared that errors did not exceed about 500 psi or 5 percent of maximum stress.

Surface Finish

Surface finish is known to be of major importance in determining fatigue strength. It appeared desirable to use a method of surface finishing which would:

(1) Leave no transverse scratches

(2) Slightly and reproducibly round edges to prevent development of "feather" edges

(3) Introduce negligible residual stresses (under 500 psi, if possible)

(4) Not cold-work the surface layers

(5) Be reasonably economical for use on the large number of specimens anticipated

(6) Satisfactorily polish the roots of deep, narrow notches in anticipation of future tests to be run on notched specimens

Several methods of mechanical polishing were tried. Electropolishing was also investigated rather thoroughly and was finally chosen as most nearly fulfilling the requirements listed above.

While a considerable amount of work was done in selecting the surface finish, the results may be summarized briefly. Electropolishing gave as high (or higher) fatigue strengths on aluminum-alloy specimens as mechanical polishing, gave as little scatter in fatigue tests, presumably introduced negligible residual stresses, did not cold-work the surface, and was relatively simple and economical. Appendix A gives details of tests which were made to justify these conclusions.

After polishing, fatigue test specimens were coated with Vinylseal for protection against corrosion and against surface damage due to handling. This coating was removed, with acetone, only immediately before testing a given specimen.

Testing Procedure

Basic fatigue-strength values were obtained by testing specimens of each type of sheet at constant-load ratios varying from $R = 0.70$ to $R = -1.00$ ($R \equiv$ Min. stress/Max. stress). The range covered, as far as feasible, the values of fatigue strength for each material.

Fatigue Damage Tests

Fatigue damage tests were made for each material at a constant mean stress of one-fourth the ultimate tensile strength of that material. While this procedure has not been generally followed previously (references 6 to 9), it seems useful for calculations with respect to gust loading (references 10 and 11). The particular value of the mean stress (one-fourth the ultimate tensile stress), while chosen arbitrarily, is one that might be used in airframe design.

Tests were taken for each material at two levels of maximum stress. These levels were chosen with the following considerations:

(1) The low level was above the relatively flat part of the S-N curve so that scatter in lifetime was not too large

(2) The high level was below the yield stress (with some question in the case of 24S-T3)

(3) The difference between stress levels was as great as possible in view of the above considerations

A test was made in the following manner: One specimen was run at the higher stress for a predetermined fraction (say, one-half) of its average expected lifetime; it was then run to failure at the lower stress. A second specimen was run in the reverse order (lower stress for one-half of its expected life, then higher stress to failure). Each test was repeated on other specimens so as to obtain average results. The tests were then repeated with several different fractional lifetimes at the first stress level.

A major purpose of these tests was to find out the effect of order of occurrence of high and low stresses.

EXPERIMENTAL RESULTS

Static Strength Tests

Table 1 gives the results of the static tension tests and the static compression tests on the three materials. The results of these static tests indicated that the sheet materials were up to standard in mechanical properties. The variations observed, from one sheet to another or from one specimen in a given sheet to another in the same sheet, were small in view of the precision possible in the fatigue tests.

Fatigue Strength Tests

Results of the fatigue tests for the 24S-T3, 75S-T6, and SAE 4130 sheet specimens are given in tables 2, 3, and 4, respectively. (Some typical specimen failures are shown in fig. 7.) These results are shown plotted in the form of S-N curves in figures 8, 9, and 10. The degree of scatter for the test data is illustrated in figure 11, which indicates that the scatter for the steel was relatively slight. Some of the S-N curves were extrapolated conservatively into the 1000- to 10,000-cycle range. Part of the difficulty in obtaining accurate values in this range, particularly at high load ratios, was attributed to the difficulty in maintaining loads well above the yield point and to the increase in strength due to the work-hardening effect. Some of the S-N curves represent intermediate test-ratio plots outlined with a few critical points and fitted into the general pattern of the more completely determined curves.

Calculations indicated that, for a region ±1/2 inch from the line of minimum cross section in each specimen, any variation in stress due to specimen shape was well within the loading precision (reference 3). The few specimens in which failures occurred beyond this region were not used in plotting the S-N curves.

When the fatigue behavior of each material had been established for stresses up to the tensile yield point, some explorations at still higher stresses were pursued. It was anticipated that a specimen so loaded in the Krouse testing machines would elongate sufficiently to cause difficulty in maintaining the mean load. This effect appeared for 24S-T3 and for SAE 4130 but was not significantly large for 75S-T6. A few specimens (not designated in the tables) of 24S-T3 were run with special precautions to apply and maintain the mean (and also maximum) stresses while the machine was running at speed.[1]

While a great deal of effort would be required to investigate thoroughly the fatigue behavior of unnotched specimens under stresses exceeding the tensile yield, this survey indicated some general trends. However, results of such tests should not be used in design.

Fatigue Damage Tests

Tables 5 through 10 give details of the damage tests, and figures 12, 13, and 14 show base-line curves used to establish mean fatigue lifetimes at high and low stress levels. Average values of "cycle ratio" plotted against "damage ratio" are shown in figures 15, 16, and 17. The quantities may be defined as follows:

n_1 number of cycles run at first stress

N_1 number of cycles in mean lifetime to failure at first stress level

n_2 number of cycles run at second stress

N_2 number of cycles in mean lifetime to failure at this second stress

[1]Loads were maintained while continually watching an oscilloscope pattern; the precision of maintaining loads was about ±5 percent.

Then

$$\text{Cycle ratio} \equiv \frac{n_1}{N_1} \equiv \text{Fractional lifetime at first level}$$

and

$$\text{Damage ratio} \equiv \frac{N_2 - n_2}{N_2} \equiv \text{Fractional lifetime lost at second level}$$

It should be emphasized that points plotted in these figures are average values for three to seven specimens each; however, scatter in data limits the significance to be attached to each point. This is discussed in the following section.

Results at Low Speed (about 90 cpm)

Tables 11, 12, and 13 show the results of fatigue tests on unnotched specimens at a machine speed of about 90 cycles per minute compared with results at a speed of about 1100 cycles per minute. Figures 18, 19, and 20 show these low-speed results in S-N diagrams in comparison with results obtained at 1100 to 1200 cycles per minute. It appears that:

(1) In the tension-tension range, there was no significant speed effect

(2) In tension-compression tests, specimens run at low speed had generally shorter lifetimes than specimens run at higher speeds

(3) The difference in lifetimes appears greater for the more ductile metals (24S-T3 and SAE 4130), greater at high maximum stresses, and greater at low values of R.

These results may have been affected by the guide plates; this possibility is discussed in a following section.

DISCUSSION OF RESULTS

Fatigue Strengths of Materials

The S-N curves of figures 8, 9, and 10 are faired curves through points plotted from observed data. In the ensuing discussion, values read from these curves are taken as fatigue strengths of the materials. Such values should not be used in design without allowance for scatter in fatigue strengths of materials. Considerable scatter has been noted in some fatigue tests of steels (reference 12) and in fatigue tests of aluminum alloys (references 13 and 14). No adequate evaluation of scatter is possible for the limited data in this report, and the results can be discussed only with this limitation in mind.

Within the limits of possible scatter, the fatigue strengths indicated in figures 8, 9, and 10 are in agreement with such other reported values as are available for comparison (references 14 and 15).

Figures 21, 22, and 23 show diagrams of stress amplitude against mean stress. Such diagrams have been suggested as means of concise representation of fatigue properties of materials and as diagrams convenient for use in design. Attention should be given to the following notes in connection with the particular representations in figures 21 to 23:

(1) "Points" are not observed values, but are values read from faired curves in figures 8, 9, and 10

(2) "Lines" are faired through these points to represent the probable behavior of the materials. Since these do not give minimum values and since data are insufficient for statistical evaluation of scatter, the lines in these diagrams should not be used for safe design values

With these qualifications, these constant-life diagrams afford a summary of S-N values for the sheet materials tested.

In two regions of each diagram, particular care should be exercised in interpreting the results. First, points for which the maximum stress exceeded the yield strength of the material (indicated on each diagram) must be considered with respect to stretching specimens and thereby altering stresses and/or material properties either preceding or during the test. This point has been mentioned in connection with details of obtaining data. This region is of relatively small importance in design, since no material (except in very local regions near stress-raisers) is expected to be used beyond its yield stress. Second, the regions where minimum stresses were in compression (to the left of the dashed line in each diagram) represent results for which the precision of measurement was less than for those in the tension-tension region. At present, because of limitations imposed by the degree of scatter, there is no certain evaluation of local stresses on the sheet specimens under reversed loading within the guide plates. However, no observations yet made have indicated serious errors due to use of guide plates in restraining buckling.

For all three materials, it appears that decreasing the mean stress increases the range of stress that can be withstood for a given lifetime, but the rate of increase is relatively small for long lifetimes. There is a possible decrease in fatigue strength as the speed of loading is decreased from 1100 to about 90 cycles per minute; this decrease appears greatest (about 10 percent) in the range of reversed stress and is barely within the precision of testing in this range. Comparing the materials on the basis of percent of ultimate tensile strength:

(1) They show rather similar short-life fatigue strengths but differ in long-life fatigue strengths; (2) the normalized SAE 4130 steel appears significantly stronger than either of the aluminum alloys for lifetimes of 100,000 cycles and over; and (3) the greatest difference between the two aluminum alloys appears for lifetimes from about 100,000 to 1,000,000 cycles (in this region, 24S-T3 shows significantly higher fatigue strength than 75S-T6). For the two aluminum alloys at longer lifetimes, there is a possible change in curvature of the constant-lifetime curves near a mean stress of about 10 percent of the ultimate tensile strength. This effect is just "on the edge" of the precision of measurement, but may be real. It does not appear for the SAE 4130 steel.

Fatigue Damage

Results of tests to measure the extent of damage or strengthening at some stress level should not be interpreted without due regard for experimental scatter. As indicated by the curves in figures 12 and 13, scatter in the base curves for the two aluminum alloys was at least ±20 percent in lifetime. Figure 14 shows less scatter - perhaps ±10 percent for the particular lot of SAE 4130 steel tested. It must be admitted, however, that tests on many more specimens might indicate wider scatter bands. Moreover, it is not easy to judge the effect of scatter in the base curves upon values of cycle ratio and values of damage ratio. The net result, however, is considerable uncertainty in these ratios. This is consistent with observed variations in damage ratios in tables 8, 9, and 10.

With these precautions in mind, the following observations may be warranted from figures 15, 16, and 17:

(1) For all three materials, damage with the low stress applied first was less than that estimated by Miner's assumption (reference 16)[2]

(2) For the steel, the application of the high stress first produced apparent damage in excess of that given by Miner's assumption

(3) For the aluminum alloys, there appeared considerable strengthening for low cycle ratios of high stress applied first

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[2]Miner's assumption is that the fractional life lost at any stress level because of running at a previous level is just the fractional life run at the first level.

Thus, $\frac{N_2 - n_2}{N_2} = \frac{n_1}{N_1}$ or, as more commonly written, $\frac{n_1}{N_1} + \frac{n_2}{N_2} = 1.$

While there are no strictly comparable data (i.e., damage on mean tensile stress), results from somewhat similar tests have been reported. Observations (1) and (2) above are in general accord with expectations on the basis of such previously reported results; item (3) is unusual.

A possible explanation for the strengthening of the 24S-T3 aluminum alloy after a few cycles of high stress may be a combination of local cold-work and local stress relief due to exceeding the yield strength at the high stress. The yield values and high stress levels for the three materials are:

Material	Yield stress, 0.2-percent offset (psi)	High stress level (psi)
24S-T3	54,000	55,000
75S-T6	76,000	65,000
SAE 4130 steel	98,500	95,000

Thus, the 24S-T3 was stressed essentially at its yield strength at the high-level load in the damage tests. However, this was not the case for the 75S-T6 (unless yielding was extremely local); and, on the other hand, the steel, which did not show much strengthening, was stressed rather near its yield.

It may be observed that very few comparable data are available on fatigue damage and more information would be of considerable interest. However, it should be kept in mind that obtaining such information may be expected to be time consuming and laborious.

CONCLUSIONS

Axial-load fatigue strengths of unnotched and polished sheet specimens of 24S-T3 and 75S-T6 aluminum alloys and of SAE 4130 steel have been determined over a wide range of stress values and lifetimes.

1. The data obtained constitute an extension of information obtained previously by other investigators and, where duplication occurs, the results are in agreement with those obtained previously.

2. Slow-speed tests (90 cpm) indicate, but have not conclusively shown, that the fatigue strength may be reduced about 10 percent when the speed of testing is changed from 1100 to 90 cycles per minute.

3. Two-stress-level tests of fatigue damage show damage ratios different from cycle ratios.

Battelle Memorial Institute
Columbus, Ohio, June 1, 1950

APPENDIX A

EFFECT OF SURFACE FINISH ON FATIGUE LIFE OF ALUMINUM-ALLOY SPECIMENS

Preliminary fatigue tests were made on both 24S-T3 specimens and 75S-T6 specimens with the following surface finishes:

(1) Mechanical polish in a basic medium; that is, abrasives which were basic

(2) Mechanical polish in a neutral or slightly acidic medium (acetic acid added to abrasives)

(3) Light buffing

(4) Electrolytic polishing

The results showed that polishing in the slightly acid medium gave somewhat higher fatigue strengths than polishing in a basic medium; buffing gave high fatigue strength but produced a cold-worked surface layer; and electrolytic polishing gave high fatigue strength and did not cold-work the surface.

Attempts were made to estimate the residual stresses in specimens subjected to the various treatments. Measurements were made on bars, $4\frac{1}{4}$ inches long by 1/2 inch wide, by removing small thicknesses electrolytically and observing the resulting curvature. Thicknesses were measured with an optical comparator. Curvature changes were determined by measuring changes in arc height over a chord length of 4 inches by means of a micrometer with an electrical contact. Stresses were computed by the following equation due to the work of Richards (reference 17):

$$S = \frac{Ew^2}{6}\frac{dc}{dw} - \frac{Ew}{2}(c_o - c) - \frac{1}{w}\int_{w}^{wc} S\,dw$$

In this equation, E is Young's modulus, w is thickness, and c is curvature (c_o being the original curvature). Table 14 shows the results of such tests on 75S-T6 and indicates appreciable compressive stress with light buffing and little significant stress due to careful mechanical polishing. The slightly higher fatigue strengths of the buffed specimens were attributed to surface work hardening and/or surface compression stresses.

In view of the previous questions as to the use of electropolishing, it was thought desirable to make more extensive tests to determine the reproducibility of results with this type of polishing. Accordingly, 20 specimens of each alloy were machined from some 2-inch-wide strips left over from shearing the original sheets. Each specimen was $17\frac{1}{2}$ inches long, 2/3 inch wide at the critical section, and had a continuous edge curvature of 12 inches. One-half of the specimens of each material were electropolished and one-half were mechanically polished using a slightly acidic medium. All specimens were tested at the same stress (55,000 psi, maximum tension, and 13,700 psi, minimum tension). The results are shown in table 15. A statistical analysis of the results was made at the Langley Aeronautical Laboratory of the NACA and the results are shown in table 16. It appeared that, so far as these tests determined, electropolishing gave quite as good results as mechanical polishing.

Finally, in view of the considerably greater ease of polishing large numbers of specimens electrolytically, this method of surface finishing was adopted.

APPENDIX B

EFFECT OF GUIDE PLATES IN TENSION-COMPRESSION FATIGUE TESTS

Several tests were made to estimate the effect of guide plates used in the tension-compression tests to prevent sheet buckling. On the basis of previous experience, the guide plates were made to allow a clearance of 0.0025 inch between either surface of the specimen and the oiled paper. To test the extent of buckling or of possible friction, slots 1/2 inch by $1\frac{1}{2}$ inches were cut in each guide plate. These slots were cut lengthwise to be over the critical test section of the test piece. Type A-7, SR-4 strain gages were cemented on either side of a specimen so as to be inside these slotted regions. Then the measurements shown in table 17 were taken with the fatigue testing machine running at rated speed. The results showed:

(1) With the clearance increased by a 0.005-inch shim separating the guide plates, there was evidence of significant buckling, especially at high compression stresses (see test 2)

(2) With no shim - the condition used for actual tests - there appeared little evidence of high bending stresses (the maximum being 950 psi in one case - test 2)

(3) Without shims, measured strains were in good agreement with values calculated from the external loads

It was concluded that the guide plates worked reasonably well for the tension-compression tests.

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TABLE 1.- STATIC TENSILE AND COMPRESSIVE STRENGTHS OF ALUMINUM

AND STEEL SHEETS USED IN FATIGUE TESTS

Material	Grain, direction	Average tensile properties			Average compressive properties	
		Elongation in 2 in. (percent)	Yield strength, 0.2-percent offset (psi) (1)	Ultimate strength (psi)	Yield strength (psi)	Modulus of elasticity (psi)
24S-T3	With	18.2	54,000	73,000	44,500	10.65×10^6
24S-T3	Cross	18.3	50,000	71,000	50,500	10.45
75S-T6	With	11.4	76,000	82,500	74,000	10.45
75S-T6	Cross	11.0	75,000	82,500	78,500	10.55
SAE 4130	With	14.25	98,500	117,000	86,000	30.4
SAE 4130	Cross	12.5	101,000	120,000	97,000	31.3

[1] Loading rate 0.03 in./min.

TABLE 2.- DIRECT-STRESS, FATIGUE TEST RESULTS

FOR 24S-T3 ALUMINUM SHEET SPECIMENS

(ULTIMATE TENSILE STRENGTH OF

SHEET, 73,000 PSI)[1] [2]

Specimen	Maximum stress (psi)	Life (cycles)	Remarks (3)
Test ratio,[4] 0.60			
A33M2	71,500	-----------	Failed during loading
A92M3	71,500	38,700	Failed in critical section
A92M4	71,500	-----------	Failed during loading
A46M2	68,000	252,000	Failed in critical section
A15M2	66,500	519,500	Do.
A2M3	65,000	7,984,400	Do.
A30M1	60,000	>10,294,000	Did not fail
Test ratio, 0.50			
A13M3	62,500	357,900	Failed in critical section
A5M3	60,000	420,300	Do.
A14M1	58,000	1,294,300	Failed 1/2 in. out of critical
A14M2	58,000	2,168,800	Failed in critical section
Test ratio, 0.40			
A33M3	71,500	42,100	Failed 1/2 in. out of critical
A92M1	71,500	16,100	Failed in critical section
A38M2	71,500	40,900	Do.
A67M2	69,000	26,100	Do.
A73M2	65,000	85,150	Do.
A93M2	63,500	63,800	Do.
A96M4	63,500	43,200	Do.
A36M3	60,000	144,100	Do.
A67M1	57,500	70,700	Failed 3/16 in. out of critical
A39M1	56,000	191,800	Failed in critical section
A43M3	54,000	66,800	Failed in flaw
A39M4	54,000	406,700	Failed in critical section
A38M4	54,000	182,600	Failed 1 in. out of critical
A40M2	54,000	351,000	Failed in critical section
A28M1	52,500	538,300	Do.
A48M4	50,000	701,100	Do.
A34M3	47,500	>10,360,000	Did not fail

[1]Static properties are given in table 1.

[2]For test results at 90 cpm, see table 11.

[3]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within the critical section are plotted on the curves.

[4]Test ratio determined by dividing minimum stress by maximum stress.

TABLE 2.- DIRECT-STRESS, FATIGUE TEST RESULTS FOR

24S-T3 ALUMINUM SHEET SPECIMENS - Continued

Specimen	Maximum stress (psi)	Life (cycles)	Remarks (3)
Test ratio,[4] 0.25			
A31M4	68,000	43,100	Failed in critical section
(5)	55,000	123,000	--------------------------
A4M4	47,500	210,500	Failed in critical section
A14M3	45,000	>12,895,700	Did not fail
A2M4	42,500	>5,256,500	Do.
Test ratio, 0.10			
A25M1	45,000	97,600	Failed 1/2 in. out of critical
A15M1	45,000	142,600	Failed in critical section
A14M4	40,000	346,100	Do.
Test ratio, 0.02			
A33M4	71,500	7,000	Failed in critical section
A91M2	71,500	4,500	Do.
A34M1	71,500	9,000	Do.
A34M4	71,500	7,000	Do.
A91M1	70,000	8,300	Do.
A33M2	65,000	29,600	Do.
A35M4	60,000	34,200	Do.
A96M3	60,000	15,900	Do.
A95M1	60,000	18,900	Do.
A1M4	60,000	43,000	Do.
A36M3	56,000	59,600	Do.
A36M2	54,000	66,300	Do.
A36M1	54,000	62,600	Do.
A39M2	54,000	72,200	Do.
A38M3	54,000	33,800	Failed 3/4 in. out of critical
A82M2	52,500	84,900	Failed in critical section
A67M3	45,000	107,000	Do.
A68M2	45,000	213,500	Failed $2\frac{1}{4}$ in. out of critical
A74M1	45,000	156,100	Failed in critical section
A46M3	38,000	9,081,200	Do.
A61M2	37,750	355,400	Do.
A79M2	36,000	267,700	Do.
A7M3	35,000	281,900	Failed in pit
A32M2	34,000	>12,362,500	Did not fail
A9M1	32,500	503,300	Failed in critical section
A13M1	31,500	>10,950,000	Did not fail
A1M3	29,000	>10,348,900	Do.
A32M4	25,000	>10,024,500	Do.

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[3]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within the critical section are plotted on the curves.

[4]Test ratio determined by dividing minimum stress by maximum stress.

[5]Mean value for specimens used in tests run for statistical analysis.

TABLE 2.- DIRECT-STRESS, FATIGUE TEST RESULTS FOR

24S-T3 ALUMINUM SHEET SPECIMENS - Concluded

Specimen	Maximum stress (psi)	Life (cycles)	Remarks (3)
Test ratio,[4] -0.30			
A37M3	70,000	3,500	Failed in critical section
A37M4	60,000	24,100	Do.
A44M3	54,000	56,600	Do.
A44M2	54,000	42,800	Do.
A31M3	50,000	66,700	Failed 1/2 in. out of critical
A32M1	50,000	93,300	Failed in critical section
A74M2	45,000	131,900	Do.
A31M1	42,500	130,000	Do.
A31M2	35,000	352,700	Do.
A26M2	30,000	>5,438,400	Did not fail
Test ratio, -0.60			
A93M4	71,500	1,600	Failed in critical section
A93M3	65,000	6,200	Do.
A1M1	55,000	8,500	Do.
A93M1	54,000	18,200	Do.
A43M4	48,000	43,100	Do.
A2M1	47,500	35,400	Do.
A73M4	40,000	118,000	Do.
A57M4	40,000	112,000	Do.
A1M2	40,000	88,100	Do.
A2M4	35,000	171,900	Do.
A29M4	30,000	231,000	Do.
A26M3	27,500	545,700	Do.
A30M4	26,000	1,164,800	Do.
A82M4	24,000	>10,994,200	Did not fail
Test ratio, -0.80			
A94M3	45,000	32,000	Failed in critical section
A3M1	35,000	149,200	Do.
A3M2	25,000	1,781,800	Do.
Test ratio, -1.00			
A5M2	50,000	13,100	Failed in critical section
A3M3	40,000	12,000	Failed 1/2 in. out of critical
A30M2	40,000	53,000	Failed in critical section
A4M2	30,000	305,700	Do.
A32M4	25,000	1,169,000	Do.

[3]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within the critical section are plotted on the curves.

[4]Test ratio determined by dividing minimum stress by maximum stress.

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TABLE 3.- DIRECT-STRESS, FATIGUE TEST RESULTS

FOR 75S-T6 ALUMINUM SHEET SPECIMENS

(ULTIMATE TENSILE STRENGTH OF

SHEET, 82,500 PSI)[1] [2]

Specimen	Maximum stress (psi)	Life (cycles)	Remarks (3)
Test ratio,[4] 0.70			
B24M1	80,000	2,478,100	Probably cold-worked
B81M4	75,000	>10,538,300	Did not fail
Test ratio, 0.60			
B91M3	80,500	14,500	Failed in critical section
B95M4	80,500	71,700	Do.
B94M1	80,500	68,300	Do.
B93M1	80,500	99,000	Do.
B15M2	79,000	162,100	Probably cold-worked
B23M4	79,000	181,600	Do.
B19M2	75,000	58,600	Failed in critical section
B19M3	70,000	88,100	Failed 1/4 in. away from critical
B39M4	70,000	432,900	Failed in critical section
B19M1	70,000	1,140,300	Reload
B16M1	65,000	>10,780,500	Did not fail
B19M1	60,000	>10,780,500	Do.
Test ratio, 0.50			
B35M3	65,000	89,000	Failed in critical section
B20M2	62,500	>4,799,800	Failed in grips
Test ratio, 0.40			
B92M3	80,500	23,600	Failed in critical section
B92M1	80,500	23,200	Do.
B122M1	80,500	20,000	Do.
B85M2	80,500	24,000	Do.
B37M4	78,000	27,600	Do.
B14M4	75,000	37,500	Do.
B8M2	70,000	39,100	Do.
B121M4	65,000	63,800	Do.
B81M1	60,000	99,200	Do.
B7M1	56,000	214,200	Do.
B78M1	52,500	>12,615,100	Did not fail
B64M3	50,000	173,200	Failed in critical section
B13M4	45,000	>15,640,700	Did not fail

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[1]Static properties are given in table 1.

[2]For test results at 90 cpm, see table 12.

[3]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within the critical section are plotted on the curves.

[4]Test ratio determined by dividing minimum stress by maximum stress.

TABLE 3.- DIRECT-STRESS, FATIGUE TEST RESULTS FOR

75S-T6 ALUMINUM SHEET SPECIMENS - Continued

Specimen	Maximum stress (psi)	Life (cycles)	Remarks (3)
Test ratio,[4] 0.25			
B36M3	62,500	52,400	Failed in critical section
(5)	55,000	74,000	--------------------------
B37M1	55,000	120,800	Failed in critical section
B23M3	50,000	>3,809,500	Did not fail
Test ratio, 0.10			
B36M2	50,000	178,000	Failed in critical section
B19M4	47,500	79,200	Failed 2 in. away from critical
B72M3	47,500	892,500	Failed in critical section
Test ratio, 0.02			
B97M3	80,500	9,400	Failed in critical section
B91M4	80,500	9,200	Do.
B91M2	80,500	9,800	Do.
B121M2	80,000	9,700	Do.
B121M1	78,000	9,700	Do.
B15M1	77,000	-----------	(Load too high; failed in grips while loading)
B38M2	75,000	16,200	Failed in critical section
B14M3	70,000	18,800	Do.
B114M4	50,000	48,000	Do.
B36M1	45,000	99,400	Do.
B14M2	45,000	160,600	Do.
B14M1	45,000	305,300	Failed in grips
B31M1	45,000	23,600	Failed 1 in. out of critical
B78M2	40,000	355,600	Failed in critical section
B65M3	38,000	70,100	Reload
B56M3	37,500	202,500	Failed 1/2 in. away from critical
B16M3	37,500	>10,500,000	Did not fail
B20M1	35,000	>13,785,100	Do.
B65M3	30,000	>10,535,800	Do.
B81M3	40,000	9,705,800	Failed in critical section
Test ratio, -0.60			
B92M2	75,000	11,600	Failed in critical section
B91M1	75,000	8,800	Do.
B92M4	75,000	9,400	Do.
B72M4	65,000	11,000	Do.
B97M2	60,000	16,600	Do.

[3]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within the critical section are plotted on the curves.

[4]Test ratio determined by dividing minimum stress by maximum stress.

[5]Mean value for specimens used in tests run for statistical analysis.

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TABLE 3.- DIRECT-STRESS, FATIGUE TEST RESULTS FOR

75S-T6 ALUMINUM SHEET SPECIMENS - Concluded

Specimen	Maximum stress (psi)	Life (cycles)	Remarks (3)
Test ratio,[4] -0.60 - Concluded			
B94M3	60,000	19,100	Failed in critical section
B44M4	60,000	19,400	Do.
B17M3	55,000	24,600	Do.
B18M3	45,000	68,200	Failed 3/16 in. out of critical
B44M2	43,000	63,800	Failed in critical section
B26M3	40,000	152,800	Do.
B26M1	40,000	168,700	Do.
B34M1	37,500	254,800	Do.
B18M4	35,000	>10,243,000	Did not fail
Test ratio, -0.80			
B46M3	50,000	15,300	Failed in critical section
B31M2	39,500	58,100	Do.
B31M4	35,000	154,700	Do.
B21M4	32,500	776,300	Failed 1/16 in. out of critical
Test ratio, -1.00			
B8M3	50,000	13,000	Failed in critical section
B109S2B	40,000	45,000	Failed 1/4 in. out of critical
B15M1	40,000	55,400	Failed in critical section
B28M3	40,000	66,800	Do.
B107S2B	35,000	135,000	Failed 1/2 in. out of critical
B39M1	35,000	110,600	Failed in critical section
B3M3	33,000	27,000	Failed 1 in. away from critical
B6M4	32,500	73,000	Probably buckled in guides
B28M1	30,000	130,200	Failed in critical (probably buckled)
B102S2B	30,000	263,000	Failed in critical section
B110S2B	30,000	165,000	Failed 1/4 in. out of critical
B101S2B	30,000	478,000	Failed in critical section
B39M2	30,000	-----------	Severely buckled
B39M3	30,000	149,300	Do.
B40M4	30,000	3,137,000	Failed in critical section
B103S2B	27,500	1,205,000	Do.
B106S2B	25,000	3,321,000	Failed 3/4 in. out of critical
B108S2B	25,000	9,497,600	Failed in critical section
B104S2B	24,000	>10,400,000	Did not fail
B105S2B	23,000	>10,133,000	Do.

[3]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within the critical section are plotted on the curves.

[4]Test ratio determined by dividing minimum stress by maximum stress.

TABLE 4.- DIRECT-STRESS, FATIGUE TEST RESULTS

FOR SAE 4130 STEEL SHEET SPECIMENS

(ULTIMATE TENSILE STRENGTH OF

SHEET, 117,000 PSI)[1] [2]

Specimen (3)	Maximum stress (psi)	Life (cycles)	Remarks (4)
Test ratio,[5] 0.60			
C144M2	110,000	>12,375,000	Did not fail; probably cold-worked
Test ratio, 0.40			
C14M1	110,000	>12,351,000	Probably cold-worked
C119M1	107,500	152,400	Failed in critical section
C29M1	102,500	>12,231,000	Did not fail
C161M1	98,000	199,300	Failed in flaw
C152M1	95,000	>12,234,100	Did not fail
C146M1	90,000	1,649,000	Do.
Test ratio, 0.25			
C20M1	98,000	>1,405,600	Failed in grip
C33M1	98,000	>13,673,500	Did not fail
C123M1	95,000	>13,395,000	Do.
Test ratio, 0.02			
C63M2	112,000	103,800	Failed in critical section
C124M1	110,000	-----------	Load could not be maintained
C161M2	107,500	89,600	Failed in critical section
C121M2	100,000	434,300	Do.
C122M2	100,000	254,500	Do.
C150M1	95,000	194,000	Do.
C8M1	95,000	247,500	Do.
C4M1	95,000	465,000	Do.
C147M2	90,000	204,400	Do.
C155M2	88,000	278,900	Do.
C38M2	85,000	>15,060,000	Did not fail
C155M1	85,000	>368,800	Do.
C58M1	82,500	>10,864,200	Do.
C151M1	80,000	>11,773,000	Do.
C147M1	70,000	>1,652,300	Do.

[1]Static properties are given in table 1.

[2]For test results at 90 cpm, see table 13.

[3]Specimens for higher maximum stress reduced in width from 1.000 to 0.800 in. to take higher loads.

[4]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within critical section are plotted on the curves.

[5]Test ratio determined by dividing minimum stress by maximum stress.

TABLE 4.- DIRECT-STRESS, FATIGUE TEST RESULTS FOR

SAE 4130 STEEL SHEET SPECIMENS - Concluded

Specimen (3)	Maximum stress (psi)	Life (cycles)	Remarks (4)
Test ratio,[5] -0.30			
C61M1	100,000	35,900	Failed in critical section
C11M1	97,500	80,000	Do.
C121M1	96,000	106,100	Do.
C32M2	95,000	83,000	Do.
C66M1	95,000	64,400	Do.
C2M2	95,000	67,600	Do.
C187M2	90,000	109,300	Do.
C188M1	85,000	239,000	Do.
C182M1	80,000	465,200	Do.
C32M1	77,500	652,400	Do.
C27M2	77,000	626,900	Do.
C174M1	74,000	874,300	Do.
C14M2	71,000	>13,086,100	Did not fail
Test ratio, -0.60			
C167M1	90,000	61,000	Failed in critical section
C189M1	85,000	49,600	Do.
C141M1	80,000	60,000	Specimen buckled
C30M2	80,000	102,400	Failed in critical section
C173M2	72,500	153,200	Specimen buckled
C96M1	72,500	300,400	Failed in critical section
C176M2	65,000	1,020,400	Do.
C10M1	62,500	2,607,900	Do.
C24M2	59,000	>12,612,400	Did not fail
Test ratio, -0.80			
C66M1	75,000	56,400	Failed in critical section
C6M2	70,000	151,000	Do.
C7M1	65,000	221,700	Do.
C113M1	60,000	4,404,200	Do.
C7M2	60,000	863,500	Failed 1 in. out of critical
C10M1	55,000	>11,959,500	Did not fail
Test ratio, -1.00			
C13M2	75,000	8,400	Failed in critical section
C50M2	65,000	98,800	Do.
C80M2	55,000	246,000	Do.
C58M1	50,000	1,530,800	Do.
C64M2	47,500	3,874,800	Do.
C47M1	45,000	>13,657,000	Did not fail

[3]Specimens for higher maximum stress reduced in width from 1.000 to 0.800 in. to take higher loads.

[4]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within critical section are plotted on the curves.

[5]Test ratio determined by dividing minimum stress by maximum stress.

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TABLE 5.- CHECK RESULTS FOR BASE-LINE CURVE FOR DAMAGE TESTS ON 24S-T3 ALUMINUM; MEAN STRESS CONSTANT AT 18,250 PSI (ONE-FOURTH OF ULTIMATE STRENGTH)

Specimen	Stress (psi)		Life (cycles)	Remarks (1)
	Maximum	Minimum		
A7M1	35,500	1,000	>2,151,100	Did not fail
Mean	------	-------	----------	Too close to endurance limit
A6M1	36,750	250	394,000	Failed in critical
A8M1	36,750	250	223,700	Do.
A7M2	36,750	250	195,800	Failed in scratch
A8M2	36,750	250	248,800	Failed out of critical
A8M3	36,750	250	>6,239,500	Did not fail
Mean	------	-------	----------	Too close to endurance limit
A11M3	40,000	-3,500	102,100	Failed in critical
A9M3	40,000	-3,500	50,100	Failed in flaw
A10M1	40,000	-3,500	147,900	Failed in critical
A10M2	40,000	-3,500	189,200	Do.
A9M4	40,000	-3,500	200,500	Do.
Mean	------	-------	160,500	Excluding A9M3
Av. deviation	------	-------	±35,000	Do.
A5M1	55,000	-18,500	52,000	Failed in critical
A6M2	55,000	-18,500	31,000	Do.
A7M4	55,000	-18,500	26,600	Do.
A8M4	55,000	-18,500	34,400	Do.
Mean	------	-------	36,000	----------------------
Av. deviation	------	-------	±8,100	----------------------

[1] Critical section includes area 1/2 in. either side of line of minimum cross section.

TABLE 6.- CHECK RESULTS FOR BASE-LINE CURVE FOR DAMAGE TESTS ON 75S-T6 ALUMINUM; MEAN STRESS CONSTANT AT 20,625 PSI (ONE-FOURTH OF ULTIMATE STRENGTH)

Specimen	Stress (psi)		Life (cycles)	Remarks (1)
	Maximum	Minimum		
B17M4	42,000	-750	>9,418,800	Did not fail
B16M4	42,000	-750	471,700	Failed in critical
Mean	------	-------	----------	Too close to endurance limit
B20M3	43,250	-2,000	>1,669,500	Did not fail
B17M2	43,250	-2,000	105,400	Failed in critical
Mean	------	-------	----------	Too close to endurance limit
B21M2	45,000	-3,750	66,600	Failed in critical
B18M1	45,000	-3,750	54,700	Do.
B18M2	45,000	-3,750	77,400	Do.
Mean	------	-------	66,200	---------------------
Av. deviation	------	-------	±7,700	---------------------
B13M1	57,500	-16,250	34,900	Failed in critical
B7M3	57,500	-16,250	23,200	Do.
B13M3	57,500	-16,250	38,000	Do.
Mean	------	-------	32,000	---------------------
Av. deviation	------	-------	±4,100	---------------------
B25M1	65,000	-23,750	19,300	Failed in critical
B25M2	65,000	-23,750	16,800	Do.
B21M3	65,000	-23,750	17,900	Do.
Mean	------	-------	18,000	---------------------
Av. deviation	------	-------	±900	---------------------

[1]Critical section includes area 1/2 in. either side of line of minimum cross section.

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TABLE 7.- CHECK RESULTS FOR BASE-LINE CURVE FOR DAMAGE TESTS ON SAE 4130 STEEL; MEAN STRESS CONSTANT AT 29,250 PSI (ONE-FOURTH OF ULTIMATE STRENGTH)

Specimen	Stress (psi)		Life (cycles)	Remarks (a)
	Maximum	Minimum		
C86M2	80,000	-21,500	759,100	Failed in critical
C28M2	80,000	-21,500	1,375,700	Do.
[b]C53M1	80,000	-21,500	2,494,100	Do.
Mean	------	-------	1,543,000	Too close to endurance limit
[b]C90M1	82,500	-24,000	562,000	Failed in critical
C97M1	82,500	-24,000	596,000	Do.
[b]C88M1	82,500	-24,000	591,000	Do.
Mean	------	-------	583,000	---------------------
Av. deviation	------	-------	±14,000	---------------------
[b]C4M2	85,000	-26,500	312,900	Failed in critical
[b]C69M1	85,000	-26,500	289,300	Do.
Mean	------	-------	301,100	---------------------
Av. deviation	------	-------	±11,800	---------------------
[b]C1M1	90,000	-31,500	120,900	Failed in critical
C90M2	95,000	-36,500	70,500	Do.
[b]C57M1	95,000	-36,500	62,600	Do.
[b]C59M1	95,000	-36,500	64,200	Do.
Mean	------	-------	65,800	---------------------
Av. deviation	------	-------	±3,200	---------------------
[b]C1M2	100,000	-41,500	29,200	Load too high

[a]Critical section includes area 1/2 in. either side of line of minimum cross section.

[b]Specimen reduced in width from 1.000 to 0.800 in.

TABLE 8.- RESULTS OF FATIGUE LOADING 24S-T3 ALUMINUM SHEET SPECIMENS AT TWO STRESS LEVELS WITH A CONSTANT MEAN STRESS OF 18,250 PSI (ONE-FOURTH OF ULTIMATE STRENGTH)

Specimen	Damage stress, n_1 (cycles)	Cycle ratio at damage stress, $\frac{n_1}{N_1}$	Final life, n_2 (cycles)	Damage, $N_2 - n_2$ (cycles) (1)	Damage ratio, $\frac{N_2 - n_2}{N_2}$	Remarks (2)
Damage stress, 55,000-psi maximum Testing stress, 40,000-psi maximum Virgin specimen life, N_2, 160,500 cycles						
A28M4	10	0.00025	>1,750,800	->1,750,800 -->	-∞	Did not fail
A27M3	3,600	.10	>1,247,100	->1,086,600-->	-∞	Did not fail
A27M2	3,600	.10	>5,843,500	->5,683,000 -->	-∞	Do.
Mean	-------	.10	----------	---------------	-∞	-------------------------
A28M3	9,000	.25	651,200	-490,700	-3.0	Failed in critical
A27M4	9,000	.25	468,000	-307,500	-2.1	Do.
A35M2	9,000	.25	254,700	-94,200	-.6	Failed 3/8 in. out of critical
A47M4	9,000	.25	195,000	-34,500	-.2	Failed in critical
A24M4	9,000	.25	230,600	-70,100	-.4	Do.
A22M4	9,000	.25	154,500	6,000	0	Do.
A23M3	9,000	.25	85,400	---------------	----------	Failed 1 in. out of critical
A24M3	9,000	.25	369,200	-208,700	-1.3	Failed in critical
Mean	-------	.25	----------	---------------	-.9 ± 0.6	Excluding A23M3 and A28M3
A11M2	18,000	.50	110,500	50,000	.3	Failed in critical
A11M4	18,000	.50	121,000	39,500	.2	Do.
A10M3	18,000	.50	177,500	-17,000	-.1	Do.
Mean	-------	.50	----------	---------------	.1 + 0.2	-------------------------
A6M3	24,000	.67	35,100	125,400	.8	Failed in critical
A6M4	24,000	.67	55,500	105,000	.7	Do.
A12M2	24,000	.67	54,300	106,200	.7	Do.
Mean	-------	.67	----------	---------------	.7 ± 0.1	-------------------------
Damage stress, 40,000-psi maximum Testing stress, 55,000-psi maximum Virgin specimen life, N_2, 36,000 cycles						
A25M2	32,000	0.20	23,000	13,000	0.4	Failed in critical
A53M1	32,000	.20	26,000	10,000	.3	Do.
A26M1	32,000	.20	39,000	-3,000	-.1	Do.
Mean	-------	.20	----------	---------------	.2 ± 0.2	-------------------------
A37M2	60,000	.37	44,200	-8,200	-.2	Failed 1/8 in. out of critical
A37M1	55,000	.34	30,400	5,600	.2	Failed in critical
A22M3	56,000	.35	33,400	2,600	.1	Do.
Mean	-------	.35	----------	---------------	0 + 0.2	-------------------------
A24M1	88,100	.55	40,500	-4,500	-.1	Failed in critical
A27M1	88,100	.55	33,600	2,400	.1	Do.
A11M1	80,000	.50	46,200	-10,200	-.3	Do.
Mean	-------	.53	----------	---------------	-.1 ± 0.1	-------------------------
A29M1	112,500	.72	24,800	11,200	.3	Failed 1/4 in. out of critical
A30M3	112,500	.78	56,900	-20,900	-.6	Failed in critical
A21M3	112,000	.75	51,100	-15,100	-.4	Do.
A22M1	112,000	.75	25,400	10,600	.3	Do.
A24M2	112,000	.75	44,000	-8,000	-.2	Do.
Mean	-------	.76	----------	---------------	.1 ± 0.4	Excluding A29M1
A29M3	136,500	.85	57,200	-21,200	-.6	Failed in critical
A40M3	144,500	.90	39,000	-3,000	-.1	Do.
A29M2	138,300	.87	30,000	6,000	.15	Do.
Mean	-------	.87	----------	---------------	-.2 ± 0.3	-------------------------

[1]Negative sign indicates strengthening.

[2]Critical section includes area 1/2 in. either side of line of minimum cross section.

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TABLE 9.- RESULTS OF FATIGUE LOADING 75S-T6 ALUMINUM SHEET SPECIMENS AT TWO STRESS LEVELS WITH A CONSTANT MEAN STRESS OF 20,625 PSI

(ONE-FOURTH OF ULTIMATE STRENGTH)

Specimen	Damage stress, n_1 (cycles)	Cycle ratio at damage stress, $\frac{n_1}{N_1}$	Final life, n_2 (cycles)	Damage, $N_2 - n_2$ (cycles) (a)	Damage ratio, $\frac{N_2 - n_2}{N_2}$	Remarks (b)
Damage stress, 65,000-psi maximum Testing stress, 45,000-psi maximum Virgin specimen life, N_2, 66,200 cycles						
B32M1	10	0.00055	107,500	-41,300	-0.6	Failed 1/4 in. out of critical
B35M4	10	.00055	94,000	-27,800	-.4	Failed in critical
[c]B20S6	10	-------	>2,000,000	>-1,933,800	------------	------------------------------
[c]B21S6	10	-------	1,905,000	-1,838,000	-28.0	------------------------------
Mean	------	.00055	----------	-----------	-.5 ± 0.1	Excluding B20S6 and B21S6
B32M4	1,800	.10	3,230,600	-3,164,400	-48.0	Failed in critical
B32M3	1,800	.10	393,100	-326,900	-.5	Do.
B29M3	1,800	.10	282,400	-216,200	-3.3	Do.
Mean	------	.10	----------	-----------	-17.3 ± 24.0	Scatter very large
B33M4	4,500	.25	112,500	-46,300	-.7	Failed in critical
B29M4	4,500	.25	113,500	-47,300	-.7	Do.
B25M3	4,500	.25	106,300	-40,100	-.6	Do.
B24M4	4,500	.25	78,200	-12,000	-.2	Do.
Mean	------	.25	----------	-----------	-.6 ± 0.1	------------------------------
B37M3	9,000	.50	28,800	37,400	.6	Failed in critical
B27M2	9,000	.50	35,600	30,600	.5	Do.
B27M3	9,000	.50	52,000	14,200	.2	Do.
Mean	------	.50	----------	-----------	.4 ± 0.2	------------------------------
B27M4	13,500	.75	22,800	43,400	.7	Failed in critical
B28M2	13,500	.75	15,000	51,200	.8	Do.
B29M1	13,500	.75	26,500	39,700	.6	Do.
Mean	------	.75	----------	-----------	.7 ± 0.1	------------------------------
Damage stress, 45,000-psi maximum Testing stress, 65,000-psi maximum Virgin specimen life, N_2, 18,000 cycles						
B22M2	16,500	.25	14,500	3,500	0.2	Failed in critical
B22M1	16,500	.25	18,100	-100	0	Do.
B28M4	16,500	.25	15,600	2,400	.1	Do.
Mean	------	.25	----------	-----------	.1 ± 0.1	------------------------------
B37M2	33,100	.50	9,800	8,200	.5	Failed in grips
B30M2	33,100	.50	16,600	1,400	.1	Failed in critical
B30M4	33,100	.50	18,700	-700	0	Do.
B30M3	33,100	.50	8,600	9,400	.5	Do.
Mean	------	.50	----------	-----------	.3 ± 0.2	------------------------------
B32M1	50,000	.76	18,400	-400	0	Failed in critical
B30M1	49,700	.75	8,600	9,400	.5	Do.
B34M3	50,000	.76	10,100	7,900	.4	Do.
B35M2	50,000	.76	7,400	10,600	.6	Do.
Mean	------	.76	----------	-----------	.4 ± 0.1	Excluding B32M1
B34M2	56,300	.85	12,500	5,500	.3	Failed in critical
B34M4	56,300	.85	9,300	8,700	.5	Do.
B34M3	56,300	.85	10,100	7,900	.4	Do.
Mean	------	.85	----------	-----------	.4 ± 0.1	------------------------------

[a]Negative sign indicates strengthening.

[b]Critical section includes area 1/2 in. either side of line of minimum cross section.

[c]Maximum stress, 76,000 psi.

TABLE 10.- RESULTS OF FATIGUE LOADING SAE 4130 STEEL SHEET SPECIMENS

AT TWO STRESS LEVELS WITH A CONSTANT MEAN STRESS OF 29,250 PSI

(ONE-FOURTH OF ULTIMATE STRENGTH)

Specimen	Damage stress, n_1 (cycles)	Cycle ratio at damage stress, $\frac{n_1}{N_1}$	Final life, n_2 (cycles)	Damage, $N_2 - n_2$ (cycles) (1)	Damage ratio, $\frac{N_2 - n_2}{N_2}$	Remarks (2)
Damage stress, 95,000-psi maximum Testing stress, 82,500-psi maximum Virgin specimen life, N_2, 583,000 cycles						
C111M1	16,500	0.25	273,600	309,400	0.5	Failed in critical
C9M2	16,500	.25	270,500	312,500	.5	Do.
C9M1	16,500	.25	135,600	447,400	.8	Do.
Mean	------	.25	-------	-------	.6 ± 0.1	-----------------
C10M1	33,000	.50	281,500	309,400	.5	Failed in critical
C8M1	33,000	.50	200,800	312,500	.7	Do.
C58M2	33,000	.50	146,800	447,400	.8	Do.
Mean	------	.50	-------	-------	.7 ± 0.1	-----------------
C50M1	49,300	.75	26,500	556,500	1.0	Failed in critical
C87M2	49,300	.75	43,100	539,900	.9	Do.
C92M1	49,300	.75	30,200	552,800	.9	Do.
Mean	------	.75	-------	-------	.9 ± 0.1	-----------------
Damage stress, 82,500-psi maximum Testing stress, 95,000-psi maximum Virgin specimen life, N_2, 65,800 cycles						
C58M2	145,000	0.25	84,000	-18,200	-0.3	Failed in critical
C10M2	145,000	.25	43,000	22,800	.3	Do.
C3M2	145,000	.25	77,000	-11,200	-.2	Do.
Mean	-------	.25	-------	-------	0 ± 0.3	-----------------
C2M2	290,000	.50	34,500	31,300	.3	Failed in critical
C13M1	290,000	.50	41,500	24,300	.4	Do.
C13M2	290,000	.50	41,200	24,600	.4	Do.
Mean	-------	.50	-------	-------	.4 ± 0.1	-----------------
C89M2	433,000	.75	39,300	26,500	.4	Failed in critical
C18M2	433,000	.75	34,400	31,400	.5	Do.
C5M2	433,000	.75	33,000	32,800	.5	Do.
Mean	-------	.75	-------	-------	.5 ± 0.1	-----------------

[1]Negative sign indicates strengthening.

[2]Critical section includes area 1/2 in. either side of line of minimum cross section.

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TABLE 11.- COMPARISON OF AXIAL FATIGUE TEST RESULTS FOR UNNOTCHED

24S-T3 ALUMINUM SHEET SPECIMENS AT TWO TEST SPEEDS

1100 cpm				90 cpm			
Specimen	Maximum stress (psi)	Life (cycles)	Remarks (1)	Specimen	Maximum stress (psi)	Life (cycles)	Remarks (1)
Test ratio,[2] -0.60							
A43M4	48,000	43,100	Failed in critical	A42M2	48,000	22,300	Failed in critical
A2M1	47,500	35,400	-------do---------	A42M3	48,000	16,200	Do.
			Failed in critical				
A1M2	40,000	88,100	-------do---------	A64M1	40,000	50,500	Failed in critical
A57M4	40,000	112,000	-------do---------	A64M2	40,000	59,800	Do.
A73M4	40,000	118,000	-------do---------	A45M4	40,000	65,600	Do.
-----	------	-----------	-----------------	A48M1	40,000	31,000	Failed 1/8 in. out of critical
-----	------	-----------	-----------------	A57M3	35,000	85,800	Failed in critical
A2M4	35,000	171,900	Failed in critical	A68M1	35,000	72,500	Do.
A26M3	27,500	545,700	-------do---------	A69M1	27,500	242,000	Do.
A82M4	24,000	>10,994,200	Did not fail	A79M3	25,000	>5,372,400	Did not fail
Test ratio, -0.30							
A44M2	54,000	42,800	Failed in critical	A43M1	54,000	36,000	Failed in critical
A44M3	54,000	56,600	-------do---------	A43M2	54,000	33,300	Do.
-----	------	-----------	-----------------	A41M4	54,000	28,400	Do.
A19M4	45,000	109,800	Failed in critical	A67M4	45,000	79,700	Failed in critical
A74M2	45,000	131,900	-------do---------	A57M2	45,000	93,600	Do.
-----	------	-----------	-----------------	A68M4	40,000	265,900	Do.
A31M2	35,000	352,700	Failed in critical	A48M3	35,000	352,500	Failed in critical
Test ratio, 0.02							
A36M2	54,000	66,300	Failed in critical	A40M4	54,000	51,600	Failed in critical
A36M1	54,000	62,600	-------do---------	A41M3	54,000	48,400	Do.
A38M3	54,000	72,200	-------do---------	-----	------	----------	-----------------
A82M2	52,500	84,900	Failed in critical	A46M1	52,500	75,500	Failed in critical
A67M3	45,000	107,000	Failed in critical	A68M3	45,000	146,800	Failed in critical
A74M1	45,000	156,100	-------do---------	A58M1	45,000	162,300	Do.
Test ratio, 0.40							
A39M4	54,000	406,700	Failed in critical	A42M1	54,000	186,500	Failed in critical
A40M2	54,000	351,000	-------do---------	A40M1	54,000	208,300	Do.
-----	------	-----------	-----------------	A42M4	54,000	362,500	Do.

[1]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within critical section are plotted in the curves.

[2]Test ratio determined by dividing minimum stress by maximum stress.

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TABLE 12.- COMPARISON OF AXIAL FATIGUE TEST RESULTS FOR UNNOTCHED

75S-T6 ALUMINUM SHEET SPECIMENS AT TWO TEST SPEEDS

1100 cpm				90 cpm			
Specimen	Maximum stress (psi)	Life (cycles)	Remarks (a)	Specimen	Maximum stress (psi)	Life (cycles)	Remarks (a)
Test ratio,[b] -0.60							
B97M2	60,000	16,600	Failed in critical	B95M3	60,000	13,600	Failed in critical
B94M3	60,000	19,100	-------do---------	B95M1	60,000	16,500	Do.
B44M4	60,000	19,400	-------do---------	B94M2	60,000	11,300	Do.
------	------	----------	------------------	B96M2	60,000	15,000	Do.
(c)	43,000	70,000	------------------	B44M1	43,000	51,000	Failed in critical
B44M2	43,000	63,800	Failed in critical	B43M4	43,000	48,300	Do.
B26M3	40,000	152,800	-------do---------	B45M1	40,000	46,100	Do.
B26M1	40,000	168,700	-------do---------	B45M4	40,000	65,000	Do.
------	------	----------	------------------	B45M3	40,000	66,700	Do.
------	------	----------	------------------	B47M4	37,500	75,800	Do.
B34M1	37,500	254,800	Failed in critical	B47M1	37,500	148,500	Do.
B18M4	35,000	10,243,000	Did not fail	B61M3	35,000	159,300	Do.
------	------	----------	------------------	B47M2	35,000	78,800	Buckled
------	------	----------	------------------	B61M4	32,500	253,600	Failed in critical
------	------	----------	------------------	B74M2	30,000	>3,756,900	Failed in grips
Test ratio, 0.02							
B97M3	80,500	9,400	Failed in critical	B89M3	80,500	6,300	Failed in critical
B91M4	80,500	9,200	-------do---------	B85M3	80,500	5,800	Do.
B91M2	80,500	9,800	-------do---------	B85M4	80,500	6,100	Do.
B121M2	80,500	9,700	-------do---------	-----	------	----------	------------------
B38M2	75,000	16,200	-------do---------	B46M2	75,000	14,200	Failed in critical
------	------	----------	------------------	B46M4	65,000	19,800	Do.
B121M3	62,500	17,900	Failed in critical	-----	------	----------	------------------
B116M4	62,500	13,800	-------do---------	-----	------	----------	------------------
------	------	----------	------------------	B36M4	55,000	34,600	Failed in critical
B114M4	50,000	48,000	Failed in critical	-----	------	----------	------------------
B14M2	45,000	160,600	-------do---------	B43M2	45,000	148,900	Failed in critical
B36M1	45,000	99,400	-------do---------	B42M4	45,000	105,800	Do.
Test ratio, 0.25							
(c)	70,000	27,500	------------------	B93M3	70,000	29,100	Failed in critical
------	------	----------	------------------	B93M4	70,000	25,100	Do.
(c)	55,000	107,700	------------------	B42M2	55,000	157,000	Failed in critical
------	------	----------	------------------	B73M4	55,000	179,600	Do.
B37M1	55,000	120,800	Failed in critical	B43M3	55,000	155,000	Do.
Test ratio, 0.40							
B85M2	80,500	24,000	Failed in critical	B94M4	80,500	22,200	Failed in critical
B92M3	80,500	23,600	-------do---------	B96M4	80,500	22,600	Do.
B122M1	80,500	20,000	-------do---------	B97M4	80,500	18,200	Do.
B92M1	80,500	23,200	-------do---------	B96M1	80,500	23,600	Do.
B121M4	65,000	63,800	Failed in critical	B47M3	65,000	70,300	Failed in critical
Test ratio, 0.60							
B95M4	80,500	71,700	Failed in critical	B41M2	80,500	224,200	Failed in critical
B94M1	80,500	68,300	-------do---------	B41M4	80,500	>94,500	Failed out of critical
B93M1	80,500	99,000	Failed in critical	B41M3	80,500	>199,700	Do.
B15M2	79,000	162,100	-------do---------	-----	------	----------	------------------
B23M4	79,000	181,600	-------do---------	-----	------	----------	------------------
(c)	80,000	45,000	------------------	-----	------	----------	------------------

[a]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within critical section are plotted on the curves.

[b]Test ratio determined by dividing minimum stress by maximum stress.

[c]Value taken from curve; within ±10 percent.

TABLE 13.- COMPARISON OF AXIAL FATIGUE TEST RESULTS FOR UNNOTCHED SAE 4130 STEEL SHEET SPECIMENS AT TWO TEST SPEEDS

1100 cpm				90 cpm			
Specimen	Maximum stress (psi)	Life (cycles)	Remarks (1)	Specimen	Maximum stress (psi)	Life (cycles)	Remarks (1)
Test ratio,[2] -0.60							
C189M1	85,000	49,600	Failed in critical	C114M1	85,000	26,800	Failed in critical
C30M2	80,000	102,400	-------do---------	------	------	----------	-----------------
				C113M2	75,000	105,500	Failed in critical
C96M1	72,500	300,400	Failed in critical	C120M1	72,500	157,600	Do.
C176M2	65,000	1,020,400	Failed in critical	C23M1	65,000	259,400	Failed in critical
C10M1	65,000	2,607,900	-------do---------	------	------	----------	-----------------
C24M2	59,000	>12,612,400	Did not fail	C23M2	60,000	>3,394,400	Did not fail
Test ratio, -0.30							
C11M1	97,500	80,000	Failed in critical	------	------	----------	-----------------
C121M1	96,000	106,100	-------do---------	------	------	----------	-----------------
C32M2	95,000	83,000	Failed in critical	C111M2	95,000	50,500	Failed in critical
C66M1	95,000	64,400	-------do---------	C44M1	95,000	48,900	Do.
C2M2	95,000	67,600	-------do---------	------	------	----------	-----------------
C187M2	90,000	109,300	Failed in critical	------	------	----------	-----------------
C188M1	85,000	239,000	Failed in critical	C112M2	85,000	189,500	Failed in critical
------	------	-------	-----------------	C137M2	85,000	139,400	Do.
------	------	-------	-----------------	C123M1	85,000	163,900	Do.
C182M1	80,000	465,200	Failed in critical	C38M1	80,000	228,200	Do.
C174M1	74,000	874,300	Failed in critical	C39M2	75,000	615,000	Failed in critical
C14M2	71,000	>13,086,100	Did not fail	C10M1	70,000	>3,557,400	Did not fail
Test ratio, 0.02							
C121M2	100,000	434,300	Failed in critical	------	------	----------	-----------------
C122M2	100,000	254,500	-------do---------	------	------	----------	-----------------
Mean	-------	-------	Scatter too great	------	------	----------	-----------------
C150M1	95,000	194,000	Failed in critical	C103M1	95,000	584,700	Failed in critical
C8M1	95,000	247,500	-------do---------	C108M2	95,000	454,200	Do.
C4M1	95,000	465,000	-------do---------	C78M1	95,000	227,900	Do.
C147M2	90,000	204,400	Failed in critical	C79M1	90,000	294,000	Failed in critical
------	-------	-------	-----------------	C5M2	90,000	439,500	Do.

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[1]Critical section includes area 1/2 in. either side of line of minimum cross section. Only results obtained from specimens failing within critical section are plotted on the curves.

[2]Test ratio determined by dividing minimum stress by maximum stress.

TABLE 14.- RESIDUAL STRESSES RESULTING FROM DIFFERENT TYPES OF SURFACE FINISH ON 75S-T6 ALUMINUM

Specimen finish	Thickness, w (in.)	Change in thickness, Δw (in.)	Change in arc height, Δa (in.)	Residual stress (psi) (1)
As received	0.0879	------	-------	----------------------
	.0869	0.0010	0.0001	650 ± 650 tension
	.0857	.0012	.0001	325 ± 325 tension
Mechanical polish	.0920	------	-------	----------------------
	.0910	.0010	.00015	1000 ± 750 tension
	.0900	.0010	-.00010	300 ± 300 compression
Buffed	.0880	------	-------	----------------------
	.0870	.0010	-.0002	1200 ± 800 compression
	.0859	.0011	-.0002	600 ± 600 compression

[1]Stress-relieved by indicated removal of metal (see text). Error estimated from precision of measurements of w and a (each measured to about 0.00005 in.).

TABLE 15.- FATIGUE RESULTS ON ELECTROPOLISHED AND MECHANICALLY POLISHED SPECIMENS[1] TESTED AT MAXIMUM LOAD OF 55,000 PSI AND TEST RATIO OF 0.25 FOR STATISTICAL ANALYSIS

Specimen (2)	Alloy	Lifetime (cycles)	
		Electropolished	Mechanically polished (3)
A1S6	24S-T3	139,400	122,000
A2S6	24S-T3	149,600	81,400
A3S6	24S-T3	73,000	86,500
A4S6	24S-T3	-------	78,800
A5S6	24S-T3	97,400	-------
A11S6	24S-T3	80,300	-------
A12S6	24S-T3	136,900	175,800
A13S6	24S-T3	93,000	114,900
A14S6	24S-T3	180,000	77,100
A15S6	24S-T3	-------	51,400
A16S6	24S-T3	153,200	69,100
A17S6	24S-T3	112,800	-------
A20S6	24S-T3	-------	116,600
B1S6	75S-T6	361,800	253,300
B2S6	75S-T6	53,800	66,600
B3S6	75S-T6	77,100	65,600
B5S6	75S-T6	67,300	52,900
B6S6	75S-T6	68,400	58,600
B7S6	75S-T6	61,700	48,600
B8S6	75S-T6	117,100	88,800
B9S6	75S-T6	61,700	84,100
B16S6	75S-T6	101,200	33,800
B18S6	75S-T6	54,700	63,000

[1]Specimens 0.088 to 0.092 in. thick and 2/3 in. wide at test section.

[2]35-in. strips cut in half to provide two specimens, one of which was electropolished and other mechanically polished.

[3]Neutral or slightly acidic medium.

TABLE 16.- RESULTS OF STATISTICAL ANALYSIS[1]

Parameter	Life (cycles)		Remarks (2)
	Electropolished	Mechanically polished	
24S-T3 alloy			
Mean	123,000	96,000	Not significantly different
Median	124,000	80,000	Significantly different
Standard deviation	32,000	34,500	Not significantly different
Estimated 95 percent confidence limits	60,000-200,000	35,000-180,000	Sample too small for adequate determination
75S-T6 alloy[3]			
Mean	74,000	62,000	Not significantly different
Median	67,000	63,000	Do.
Standard deviation	20,500	16,000	Do.
Estimated 95 percent confidence limits	40,000-125,000	35,000-110,000	Sample too small for adequate determination

[1]Statistical analysis made at Langley Aeronautical Laboratory of NACA.

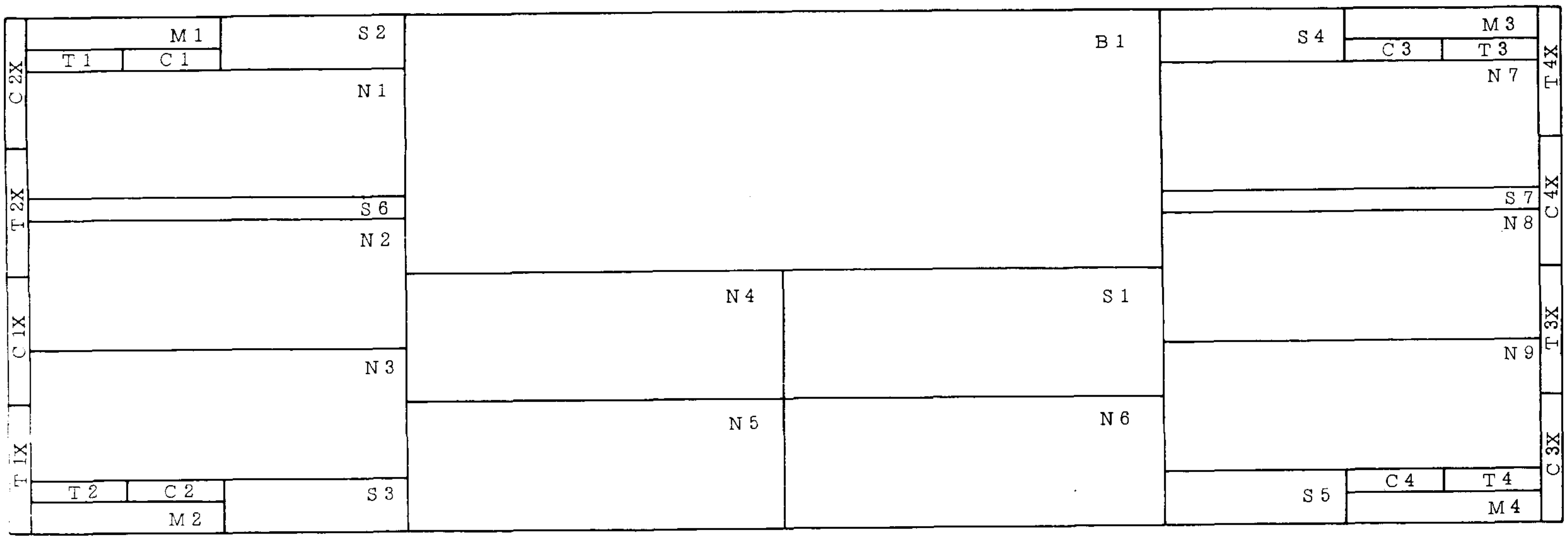
[2]5-percent level of significance was used for all tests of significant differences.

[3]Specimen B1S6 omitted from calculations.

TABLE 17.- EFFECT OF GLIDE PLATES IN TENSION-COMPRESSION FATIGUE TESTS

Side of specimen to which gage was attached	Computed values of loads (psi)	
	Maximum	Minimum
Test 1 - Sample loaded for 10,000-psi maximum; -6000-psi minimum		
(0.005-in. shim between guide plates)		
Front gage	10,225	-6,000
Rear gage	10,225	-6,360
(No shims between guide plates)		
Front gage	9,650	-6,250
Rear gage	10,750	-6,600
Test 2 - Sample loaded for 20,000-psi maximum; -12,000-psi minimum		
(0.005-in. shim between guide plates)		
Front gage	19,700	[a]-9,800
Rear gage	20,100	[a]-14,000
(No shims between guide plates)		
Front gage	20,000	-11,000
Rear gage	20,800	-12,900
Test 3 - Sample loaded for 35,000-psi maximum; -21,000-psi minimum		
Range of throw too great to be recorded with strain gages		
Test 4 - Sample loaded for 1000-psi maximum; -12,000-psi minimum		
(No shims between guide plates)		
Front gage	1,400	-12,000
Rear gage	1,090	-12,200
Test 5 - Sample loaded for 1000-psi maximum; -24,000-psi minimum		
(No shims between guide plates)		
Front gage	1,070	-24,400
Rear gage	930	-23,750
Test 6 - Sample loaded for 1000-psi maximum; -36,000-psi minimum		
(No shims between guide plates)		
Range of throw too great to be recorded with strain gages		

[a]Difference of 2000 psi in stress at front and rear indicated specimen buckled in compression. In actual tests, test pieces were run with no shims between guide plates.

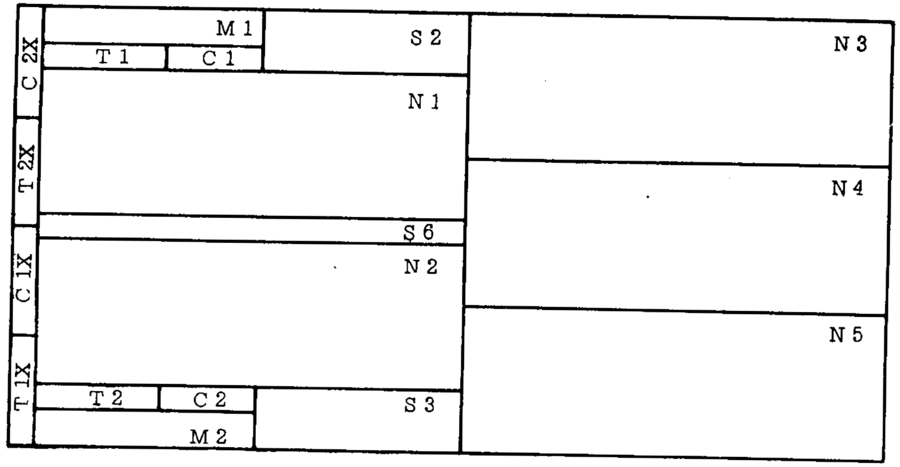


Coupons for specimens		
Designations	Dimensions (in.)	Use
B 1	24 by 70	Actual structures
C 1, C 2, C 3, C 4	2 by 9	Static compression with grain
C 1X, C 2X, C 3X, C 4X	2 by 12	Static compression across grain
M 1, M 2, M 3, M 4	3 by 18	Fatigue
N 1, N 2, N 3, N 4, N 5, N 6, N 7, N 8, N 9	12 by 35	Notched fatigue
S 1	12 by 35	Spares
S 2, S 3, S 4, S 5	5 by 17	Spares
S 6, S 7	2 by 35	Spares
T 1, T 2, T 3, T 4	2 by 9	Static tension with grain
T 1X, T 2X, T 3X, T 4X	2 by 12	Static tension across grain

Remarks

1. All sheets painted both sides with zinc chromate primer
2. Scratching avoided when laying out, shearing, and machining
3. Rubber stamp and marking ink used for numbering all specimens; the use of metal stamps on these specimens was prohibited
4. All specimens numbered as follows:
   First letter - material designation
   Letter A for 24S-T3 material
   Letter B for 75S-T6 material
   First number sequence - sheet number
   Sheets numbered in order cut
   Followed by specimen number as given on above layout
   Example:
   A150N2 indicates "24S-T3, sheet no. 150, specimen N2"
   B50T2X indicates "75S-T6, sheet no. 50, specimen T2X"
5. All specimens numbered at least four places, each side

Figure 1.- Sheet layout for aluminum specimens.



Coupons for specimens		
Designations	Dimensions (in.)	Use
C 1, C 2	2 by 9	Static compression with grain
C 1X, C 2X	2 by 9	Static compression across grain
M 1, M 2	3 by 18	Fatigue
N 1, N 2, N 3, N 4, N 5	12 by 35	Notched fatigue
S 2, S 3	5 by 17	Spares
S 6	2 by 35	Spares
T 1, T 2	2 by 9	Static tension with grain
T 1X, T 2X	2 by 9	Static tension across grain

Remarks

1. All sheets painted both sides with zinc chromate primer
2. Scratching avoided when laying out, shearing, and machining
3. Rubber stamp and marking ink used for numbering all specimens; the use of metal stamps on these specimens was prohibited
4. All specimens numbered as follows:
   First letter - material designation
   Letter C for 4130, normalized and stress-relieved material
   First number sequence - sheet number
   Sheets numbered in order cut
   Followed by specimen number as given on above layout
   Example:
   C23M1 indicates "4130, normalized and stress-relieved, sheet no. 23, specimen M1"
5. All specimens numbered at least four places, each side

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Figure 2.- Sheet layout for steel specimens.

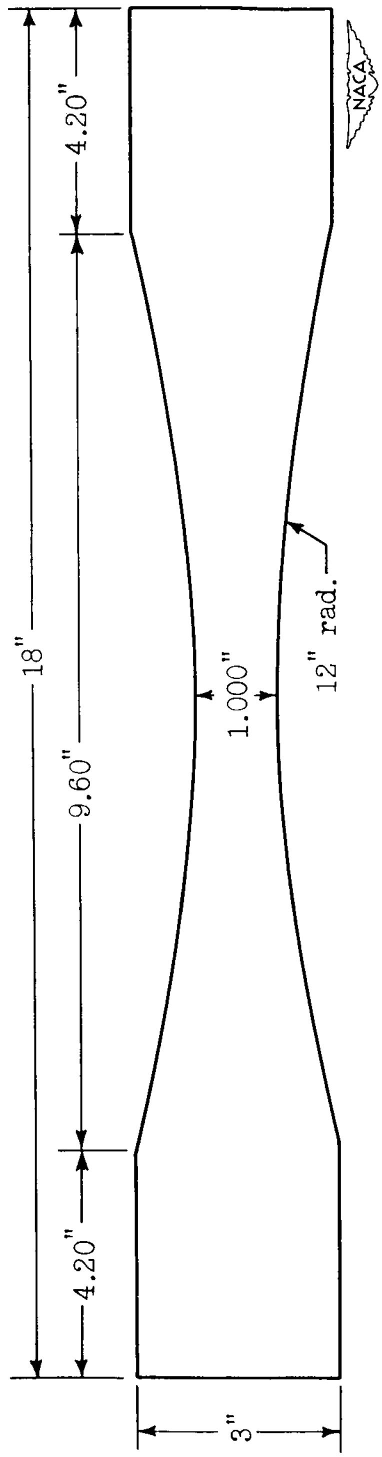


Figure 3.- Fatigue test specimen.

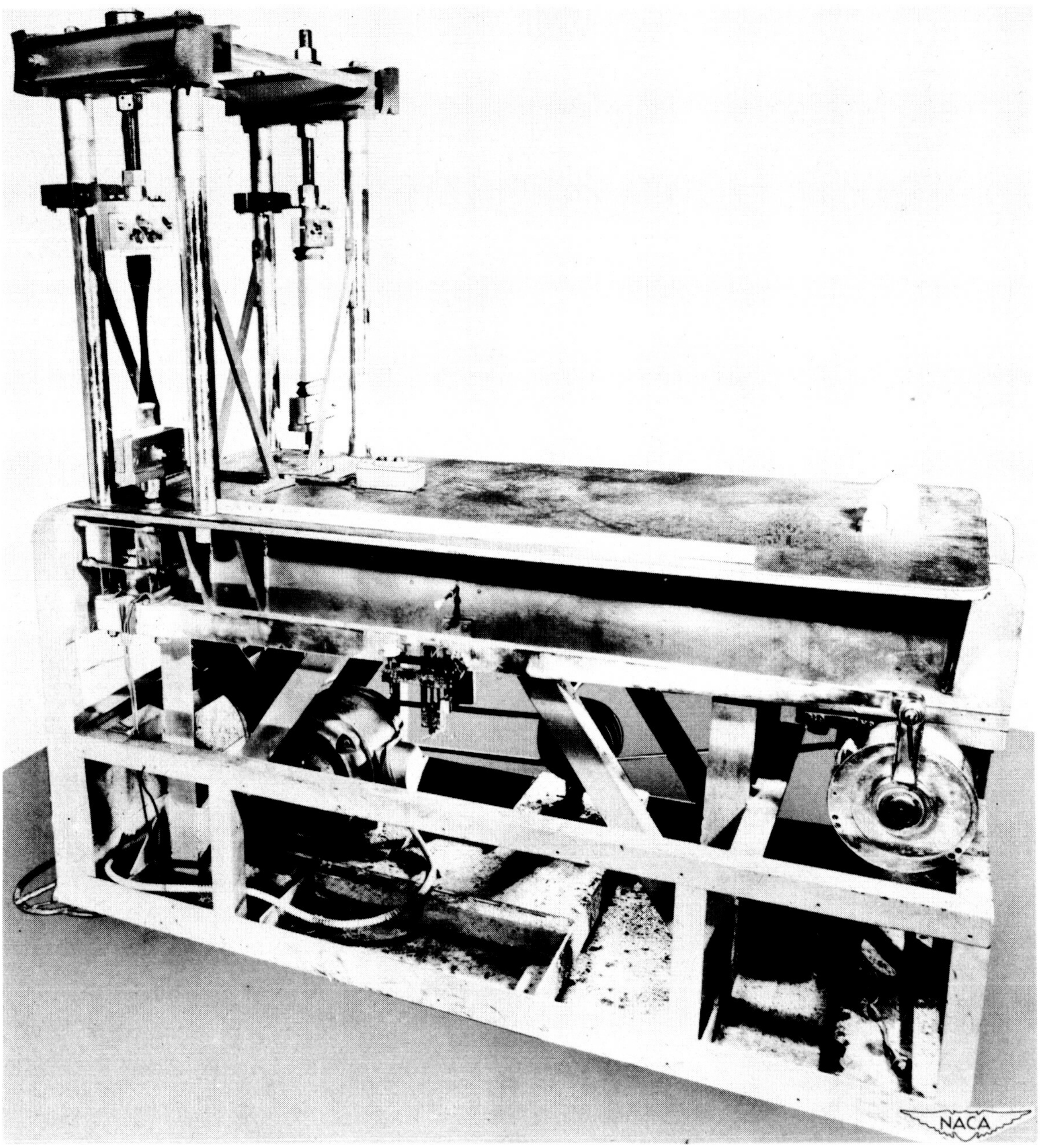


Figure 4.- Krouse 10,000-pound direct repeated-stress machine, showing specimens in position. Specimen on left shown without lateral supports; specimen on right shown with guide plates in position.

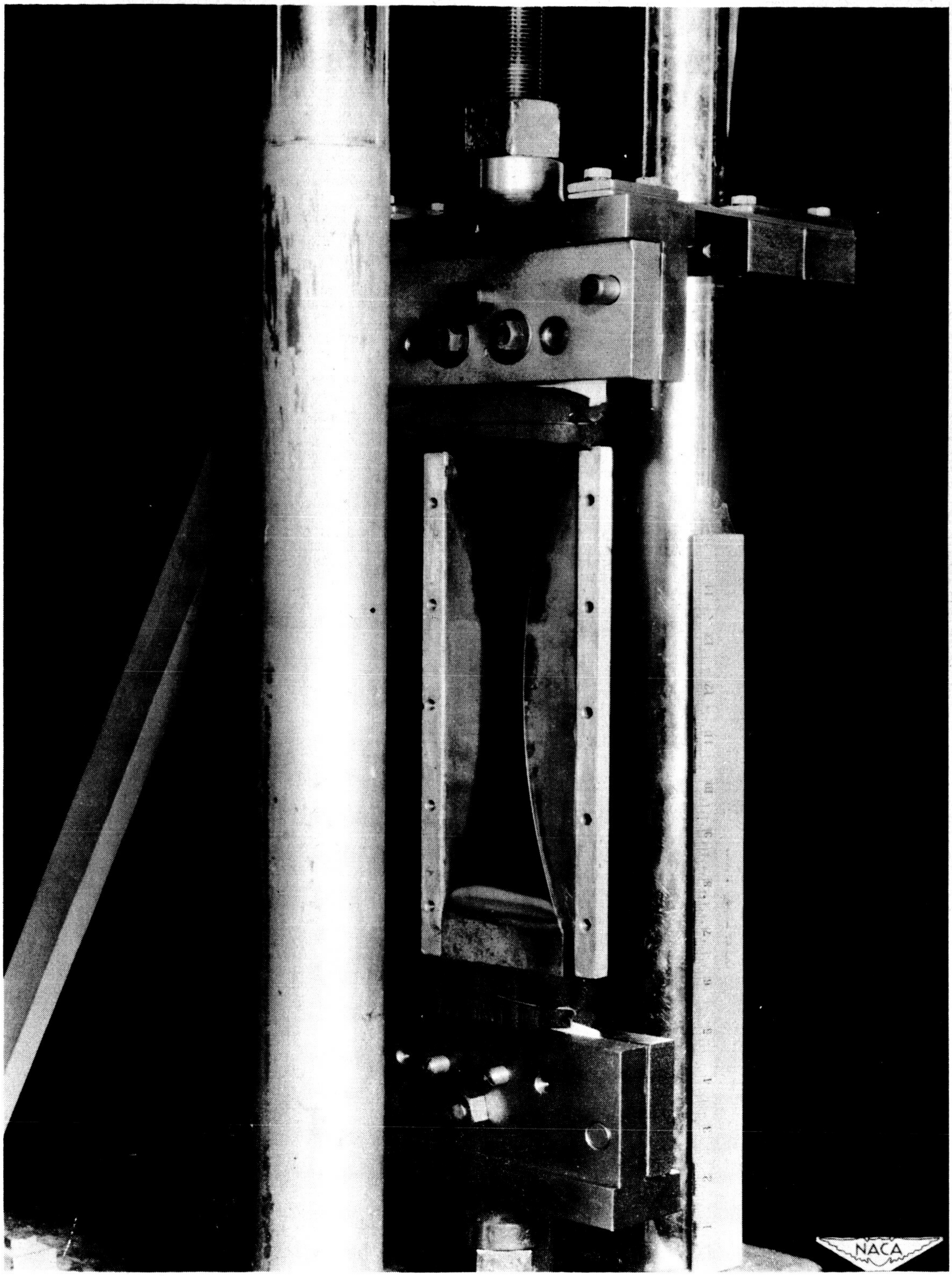
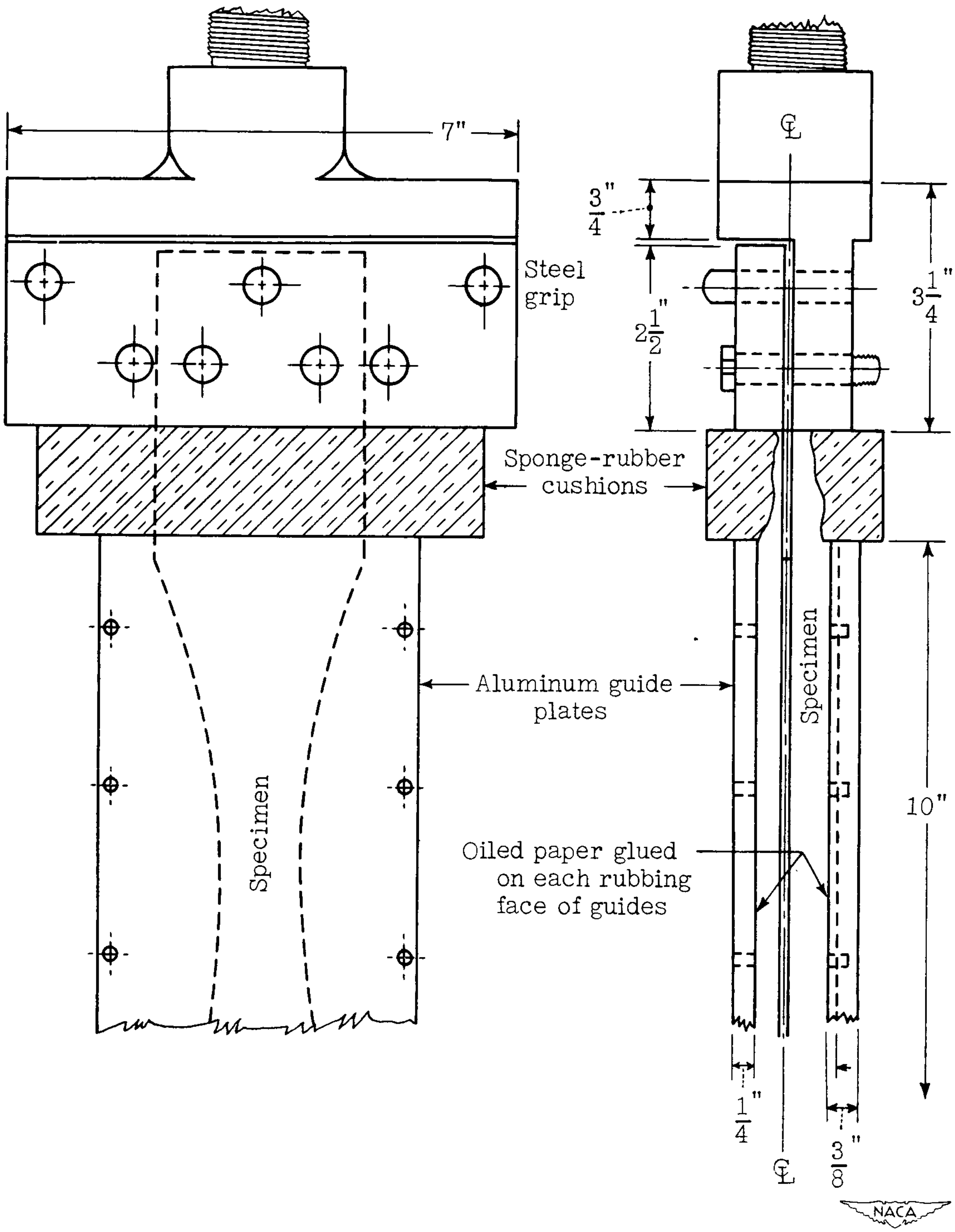


Figure 5.- Close-up view of rigid grips and guide plates in testing position. Front support removed to show details.



(a) Front view.

(b) Edge view. Guide plates shown separated.

Figure 6.- Sketch of tension-compression grips and guide plates. Only upper portion shown.

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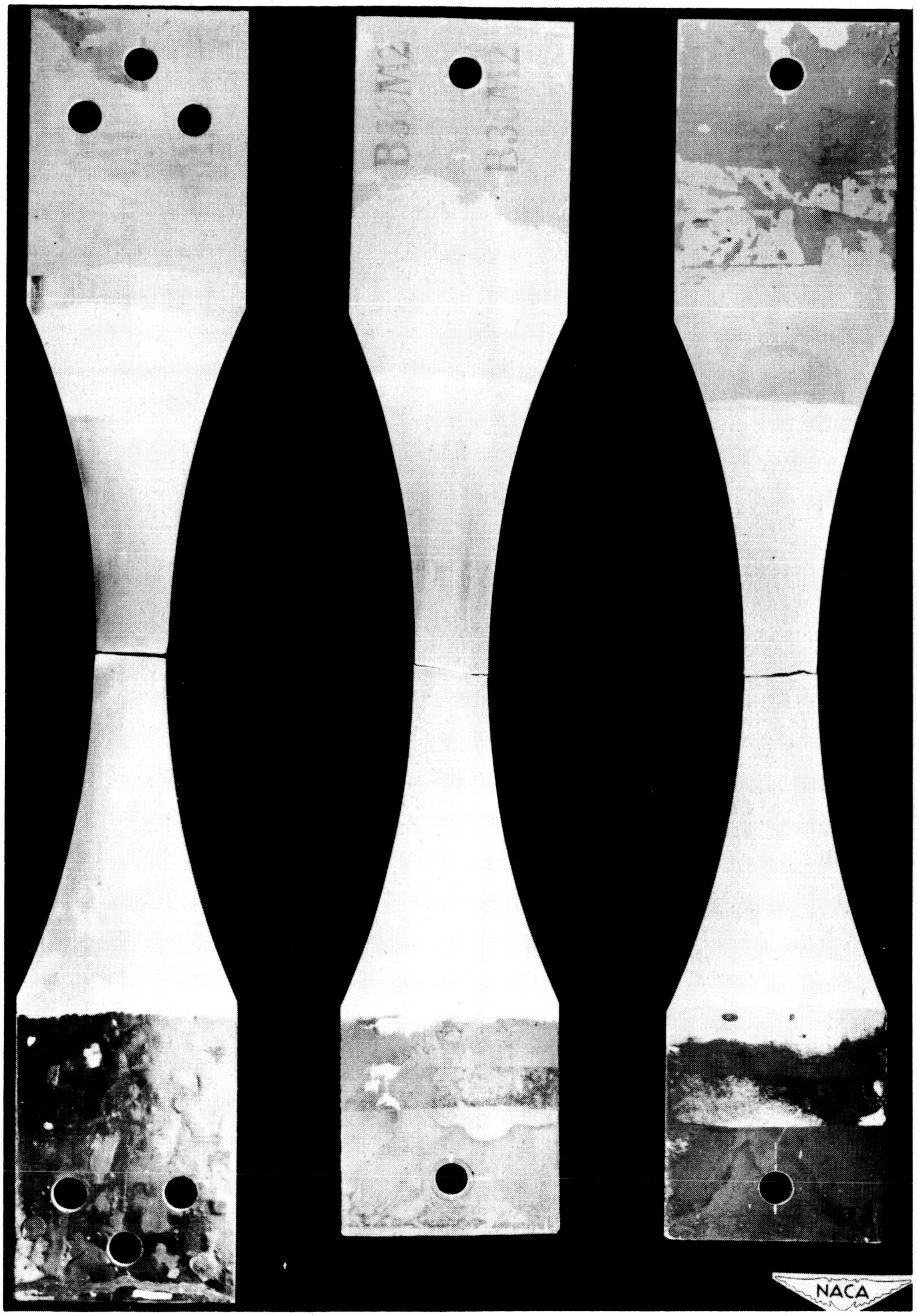

Figure 7.- Typical failures on fatigue test specimens. Left to right: SAE 4130 steel, 75S-T6 aluminum, and 24S-T3 aluminum. Scale, approximately one-half.

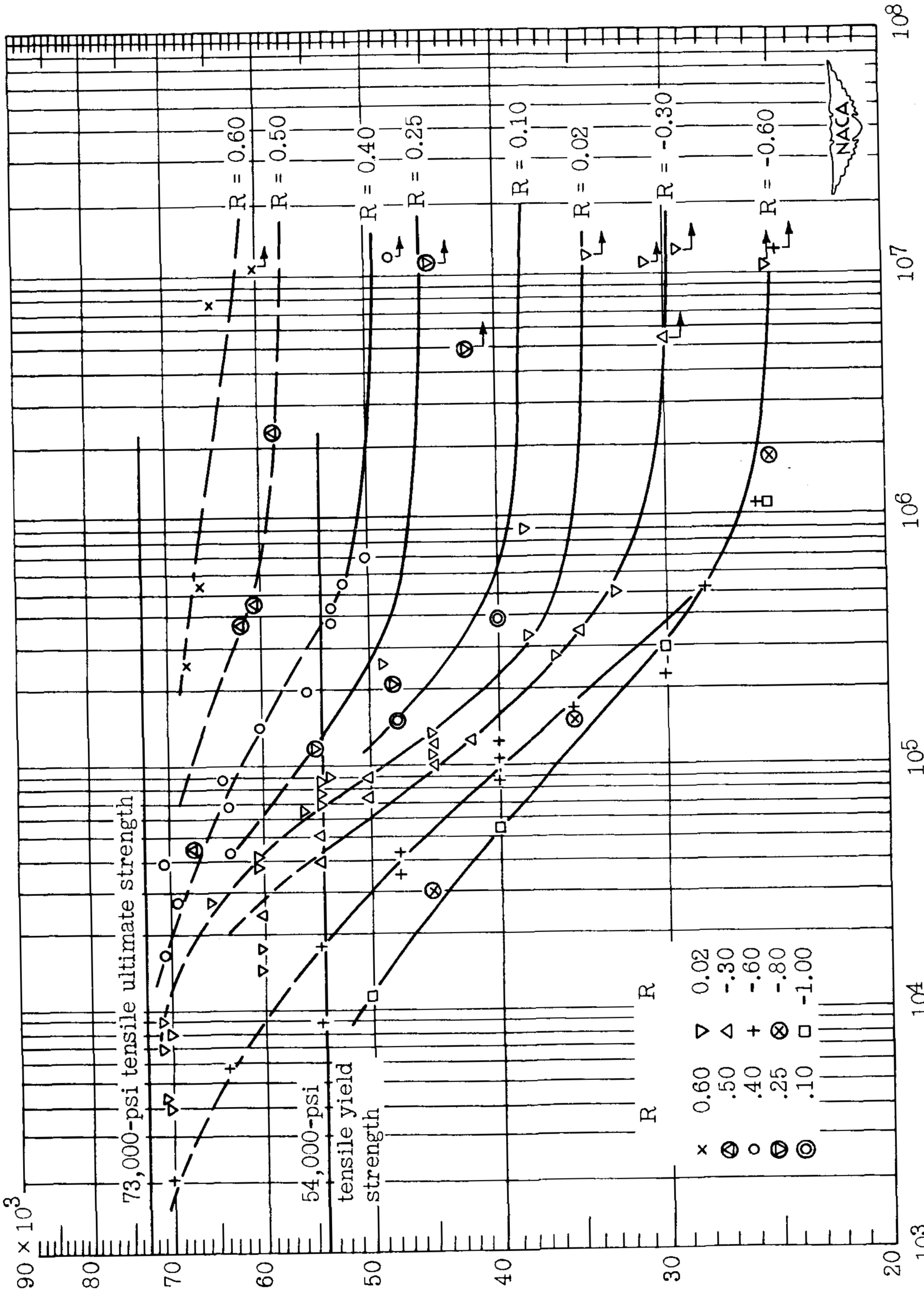

Figure 8.- Results of fatigue tests at 1100 cycles per minute on 24S-T3 aluminum alloy.

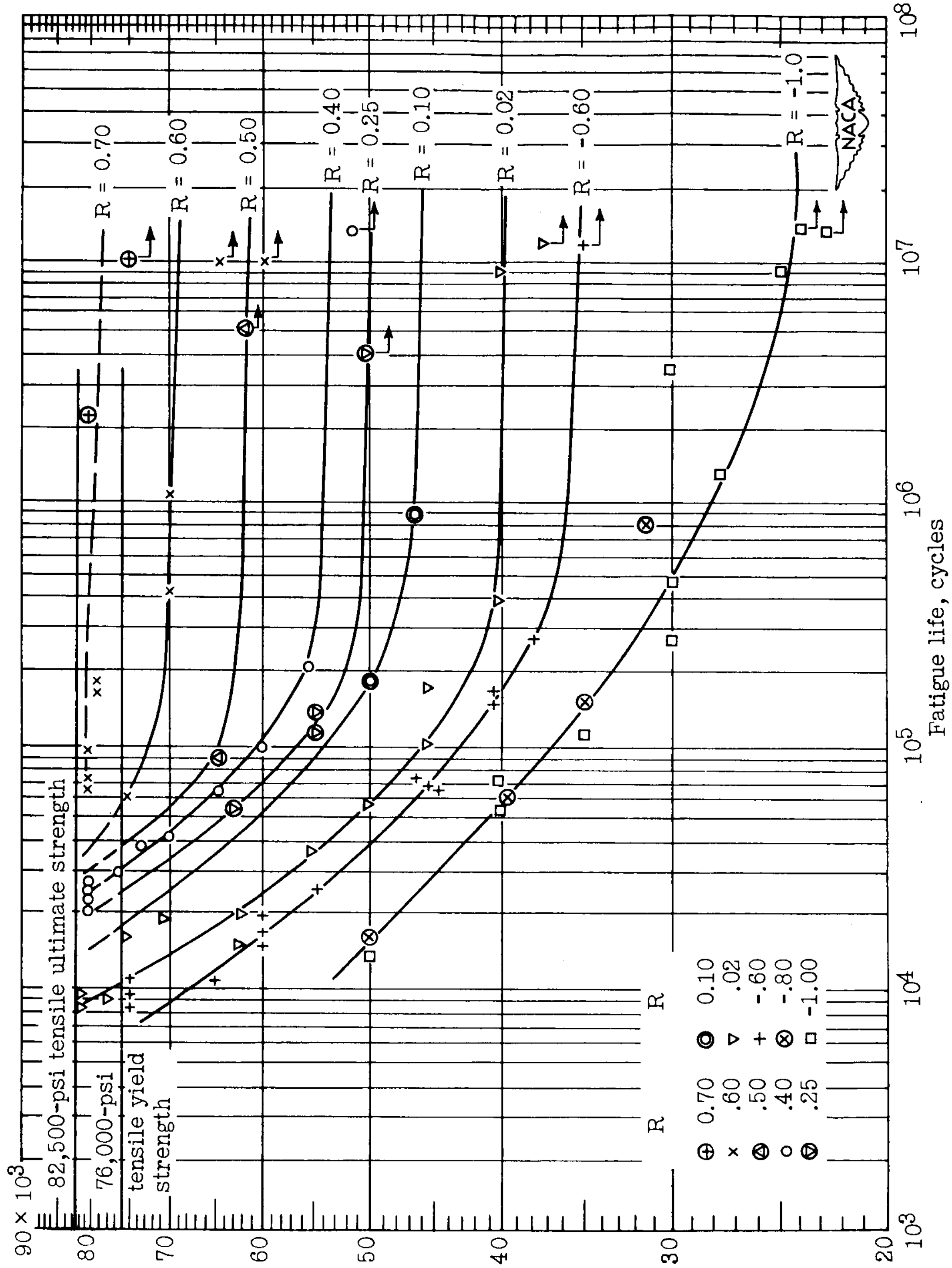

Figure 9.- Results of fatigue tests at 1100 cycles per minute on 75S-T6 aluminum alloy.

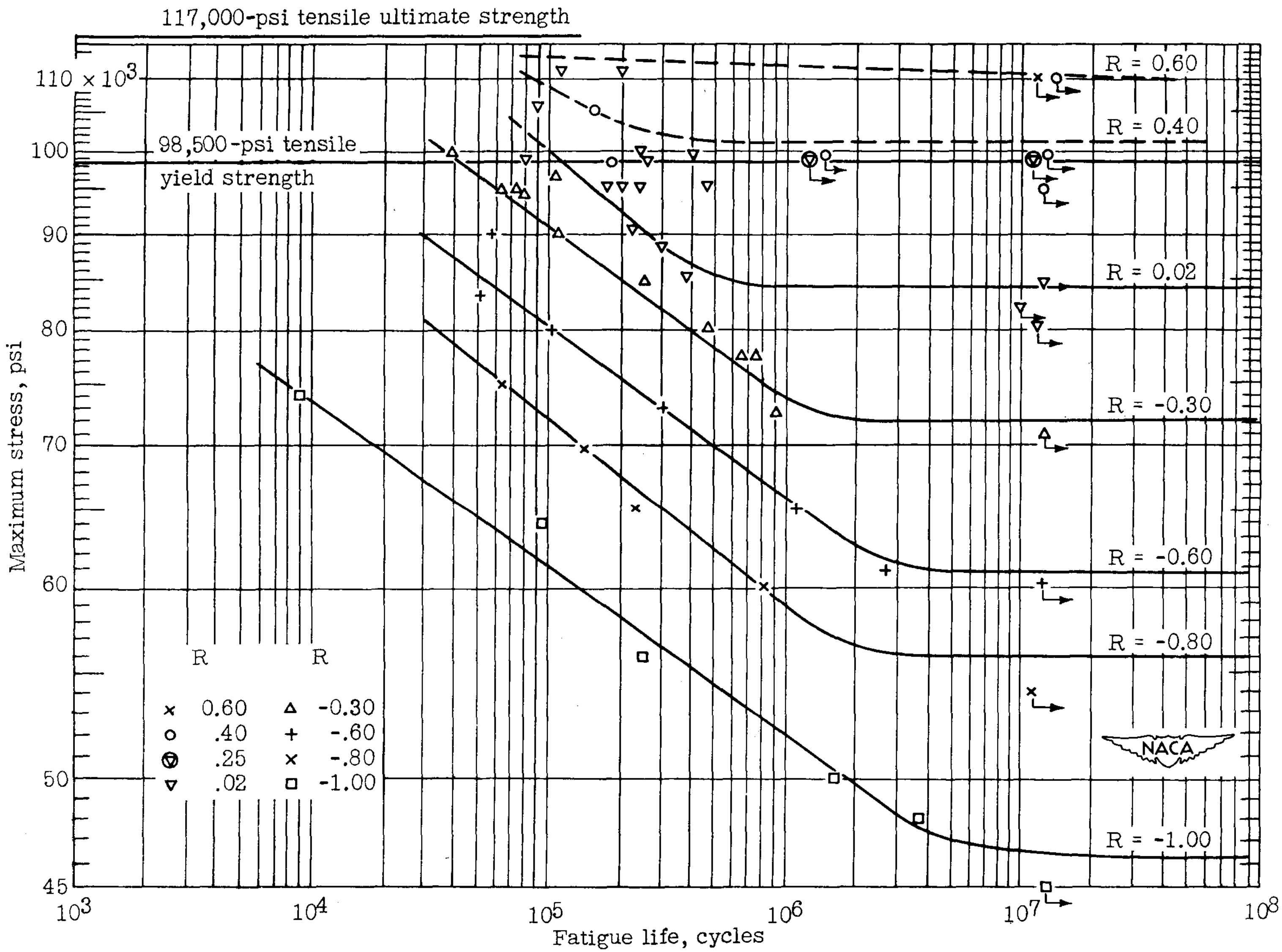

Figure 10.- Results of fatigue tests at 1100 cycles per minute on normalized SAE 4130 steel.

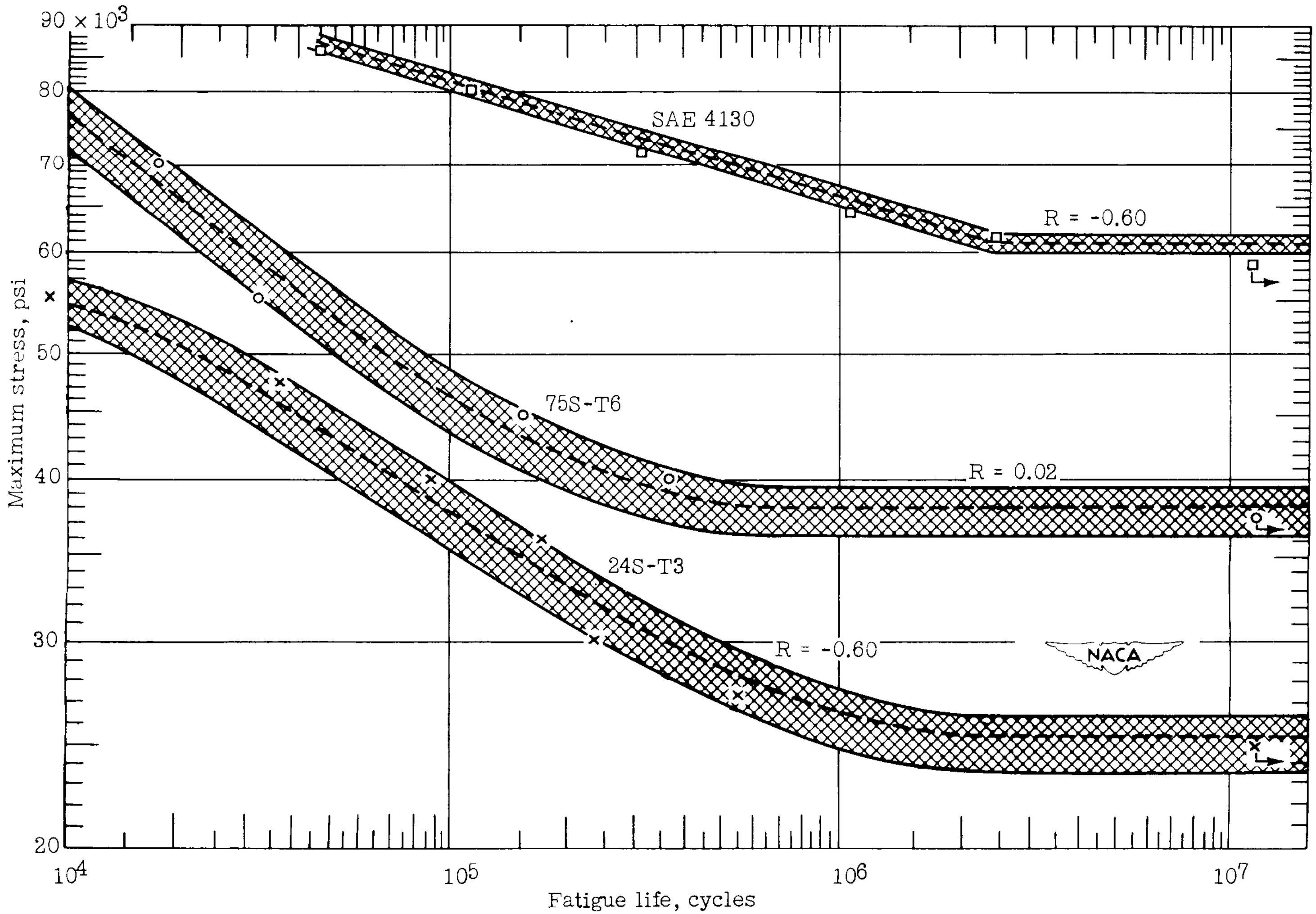

Figure 11.- Representative scatter bands. Dashed lines correspond to solid lines in figures 8, 9, and 10. The ratio shown for 75S-T6 is R = 0.02 to avoid confusion with the scatter bands at R = -0.60 for 24S-T3 and 4130.

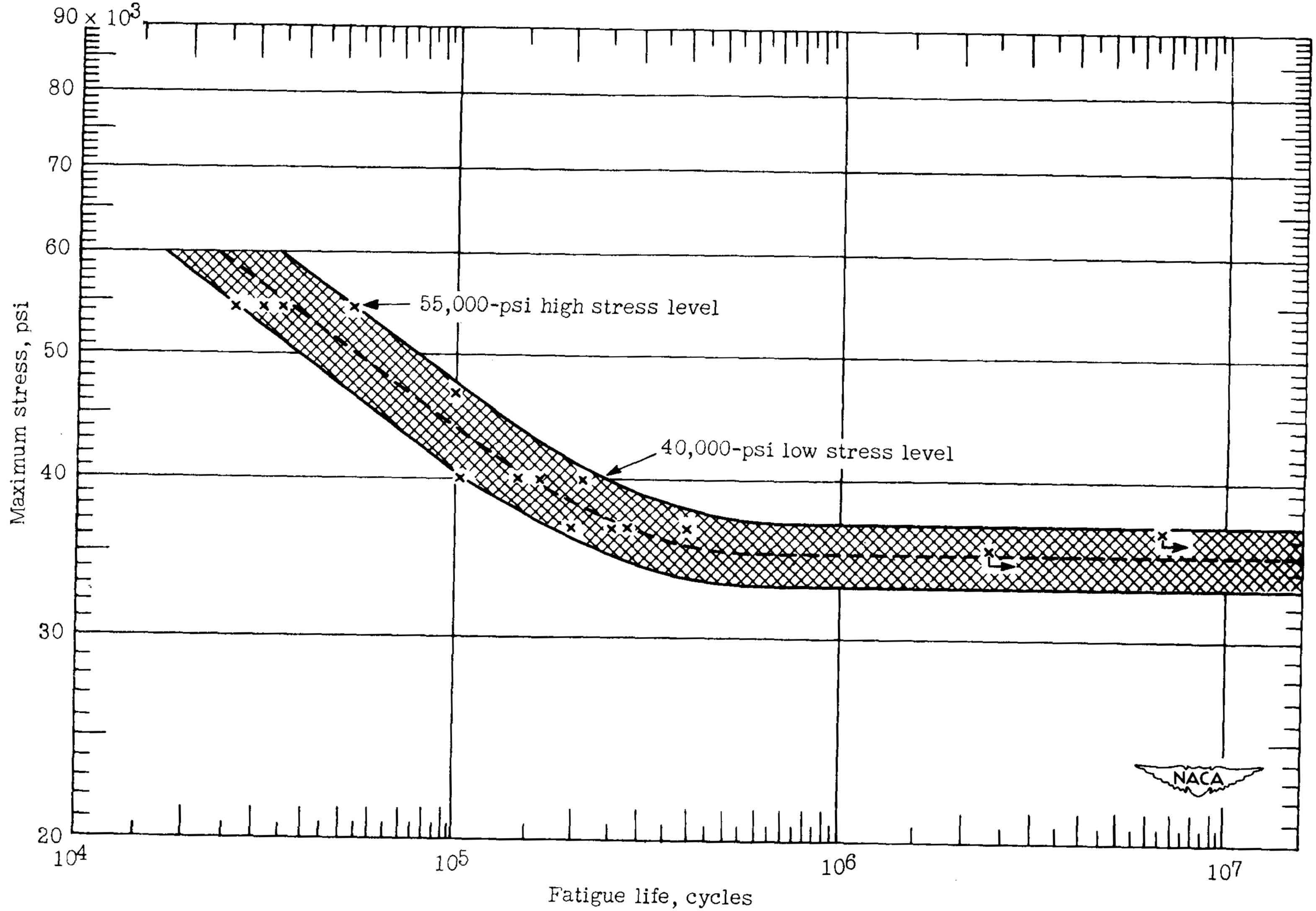

Figure 12.- S-N base-line curve for damage tests on 24S-T3 aluminum. Mean stress constant at 18,250 psi (one-fourth of ultimate strength).

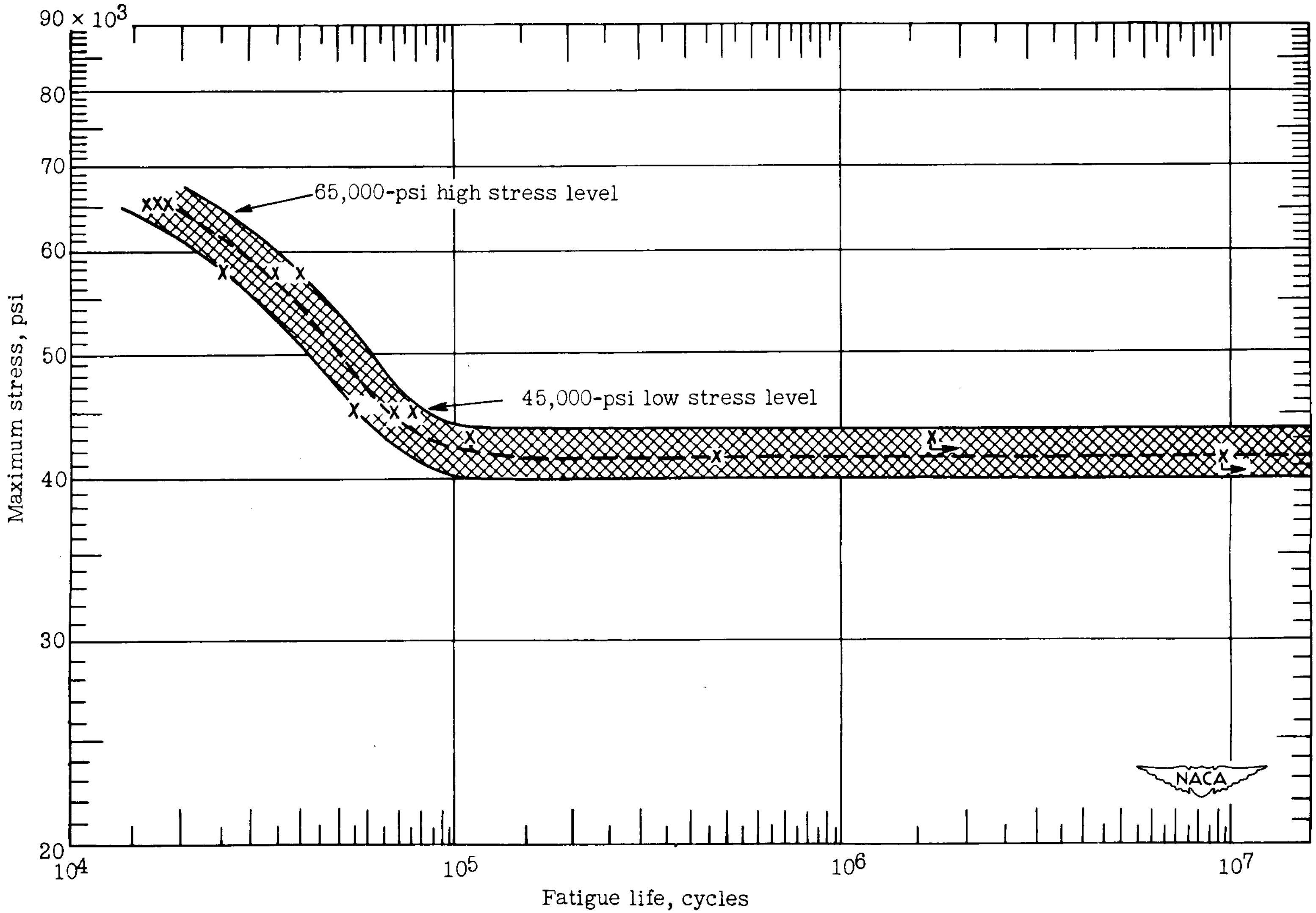

Figure 13.- S-N base-line curve for damage tests on 75S-T6 aluminum. Mean stress constant at 20,625 psi (one-fourth of ultimate strength).

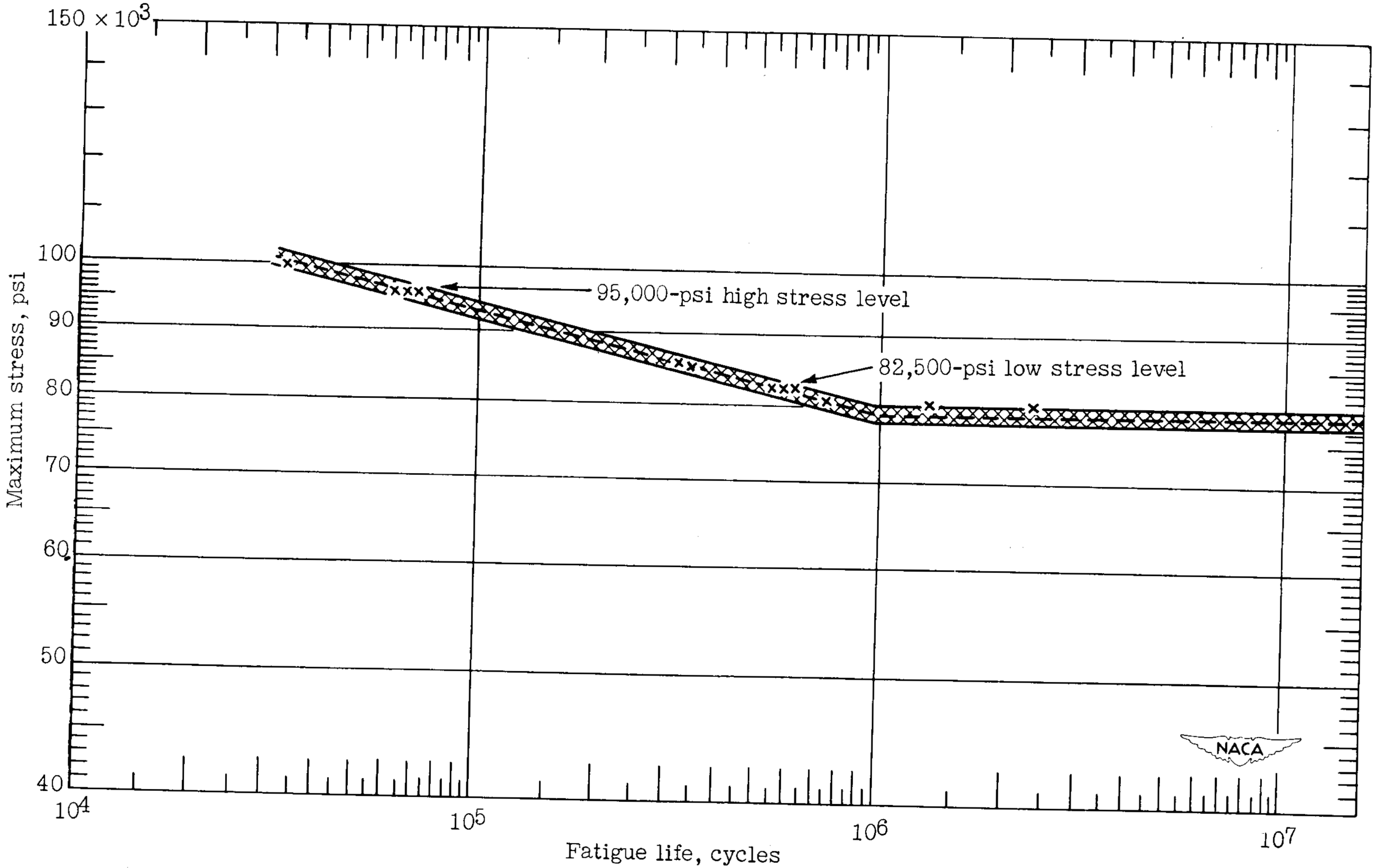

Figure 14.- S-N base-line curve for damage tests on SAE 4130 steel. Mean stress constant at 29,250 psi (one-fourth of ultimate strength).

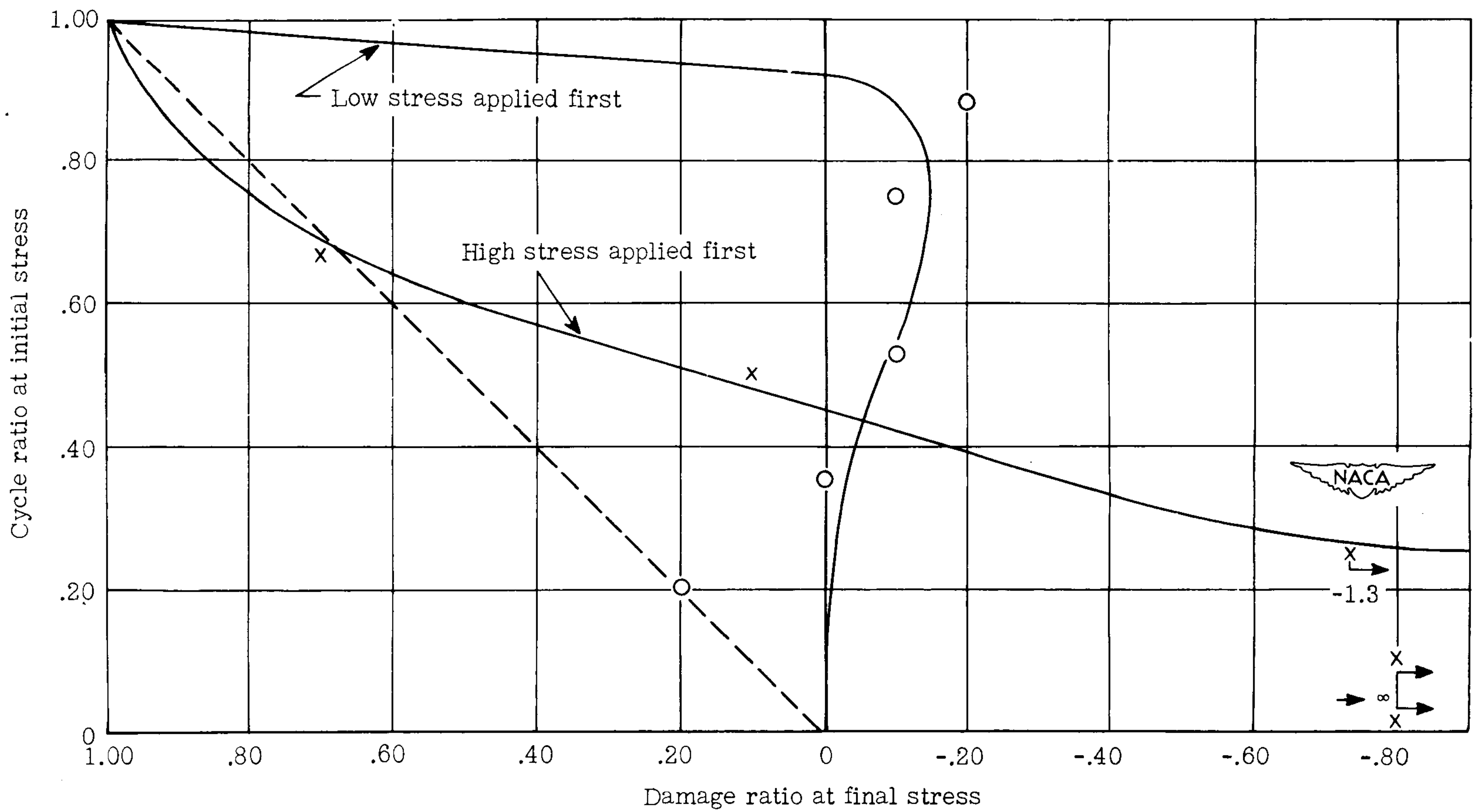

Figure 15.- Results of fatigue loading 24S-T3 aluminum sheet specimens at two stress levels. High stress, 55,000-psi maximum; low stress, 40,000-psi maximum; for both, mean stress, 18,250 psi.

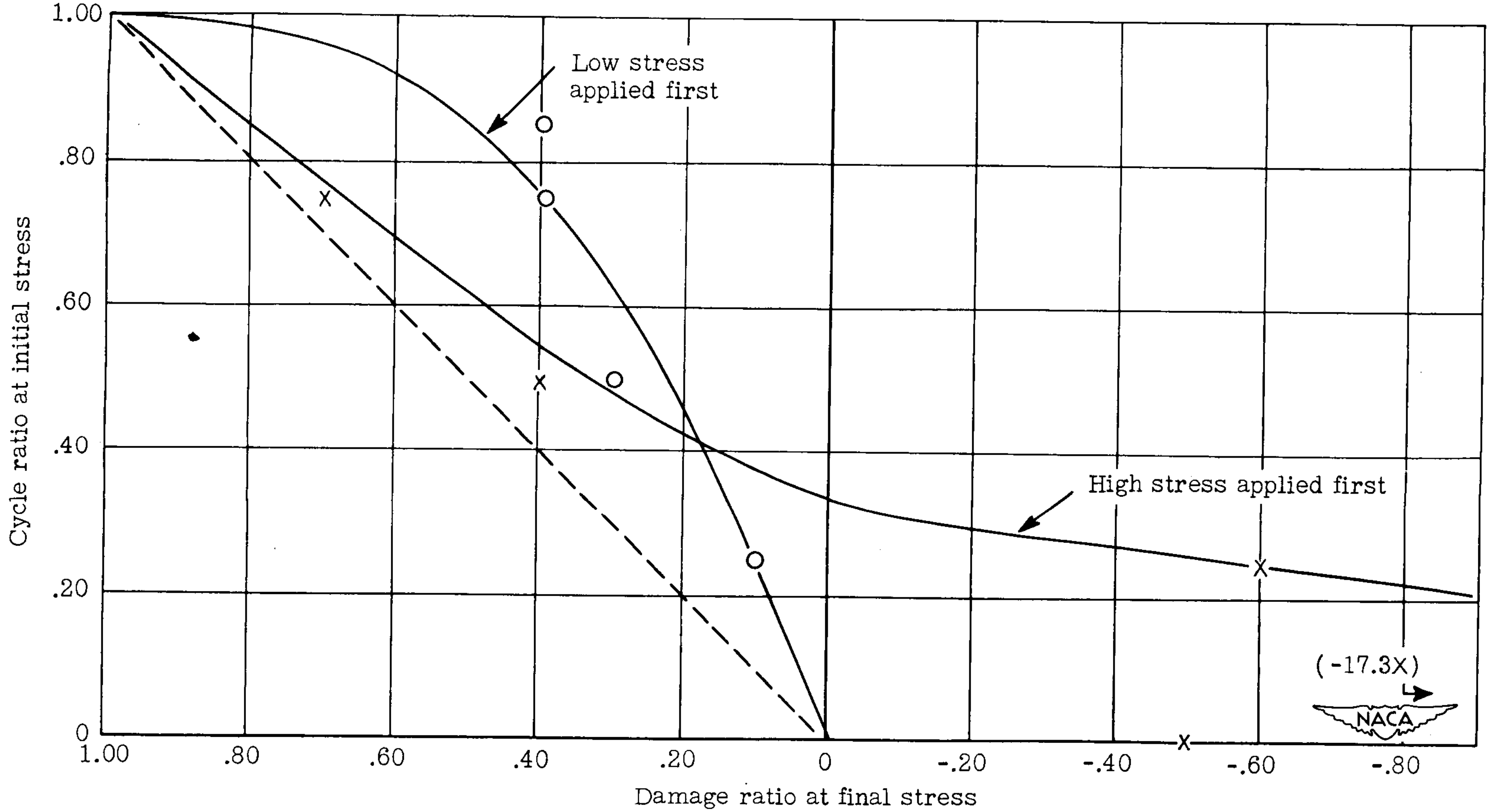

Figure 16.- Results of fatigue loading 75S-T6 aluminum sheet specimens at two stress levels. High stress, 65,000-psi maximum; low stress, 45,000-psi maximum; for both, mean stress, 20,625 psi.

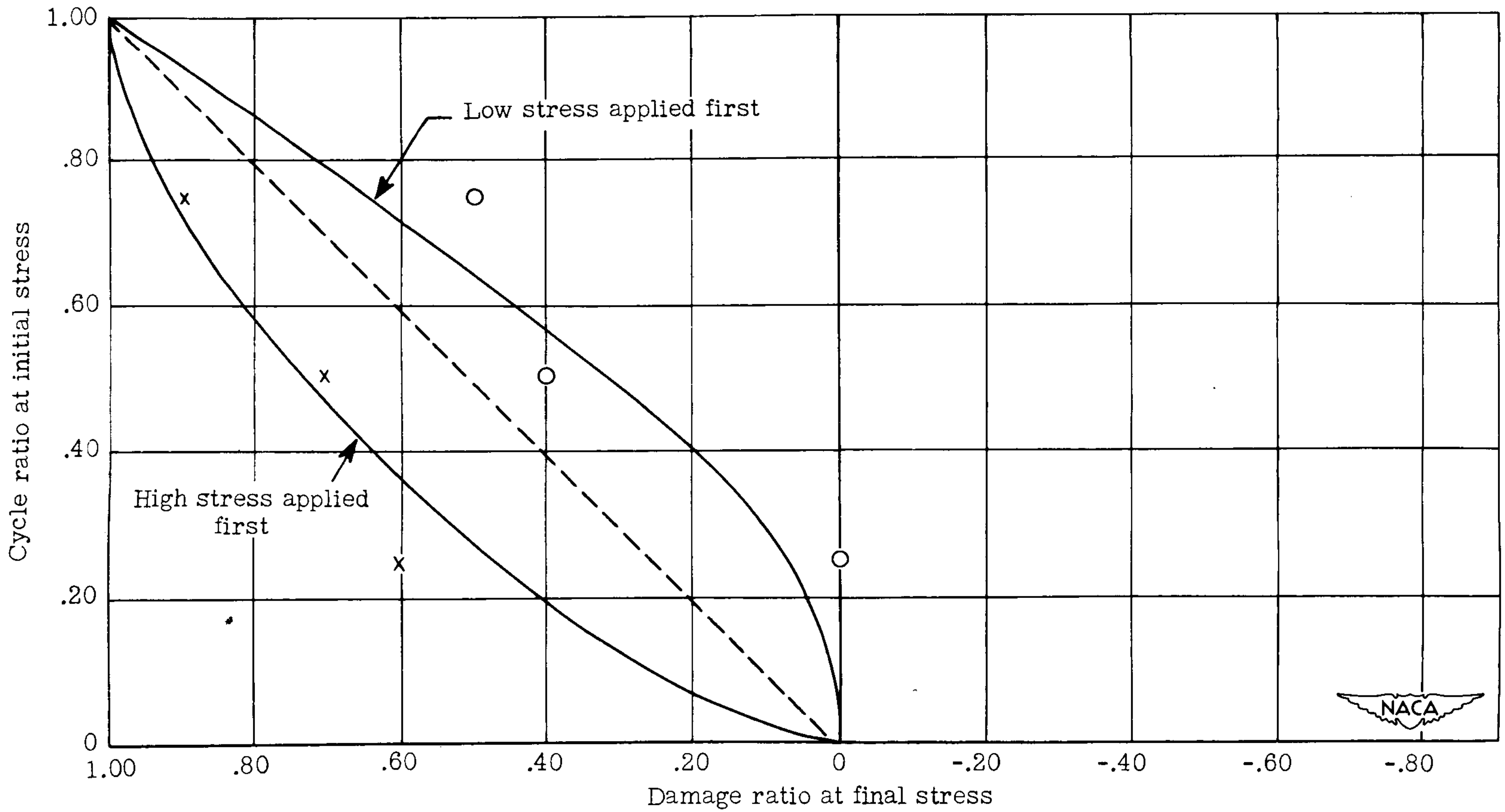

Figure 17.- Results of fatigue loading SAE 4130 steel sheet specimens at two stress levels. High stress, 95,000-psi maximum; low stress, 82,500-psi maximum; for both, mean stress, 29,250 psi.

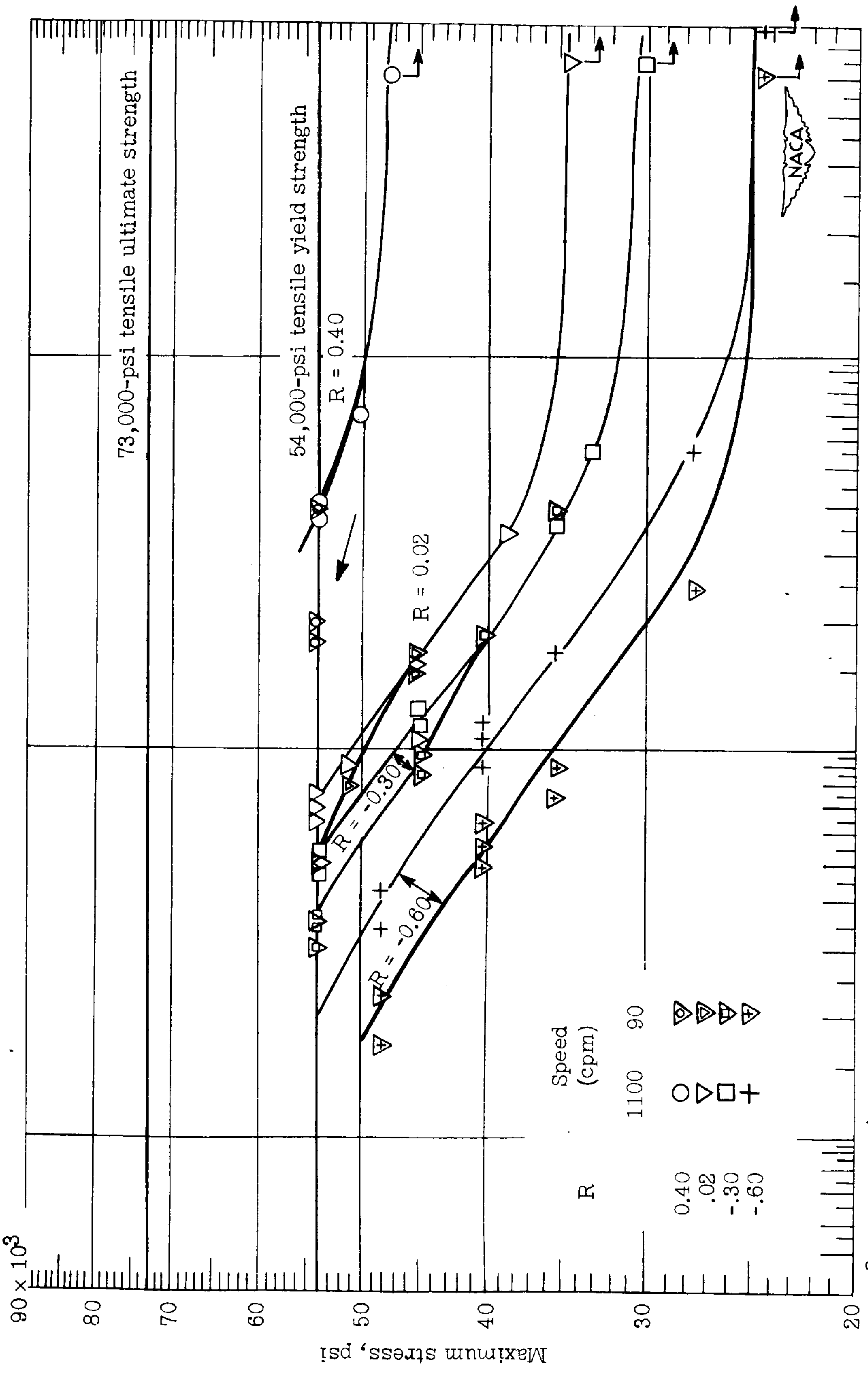

Figure 18.- Results of fatigue tests, at different speeds, on unnotched 24S-T3 aluminum alloy.

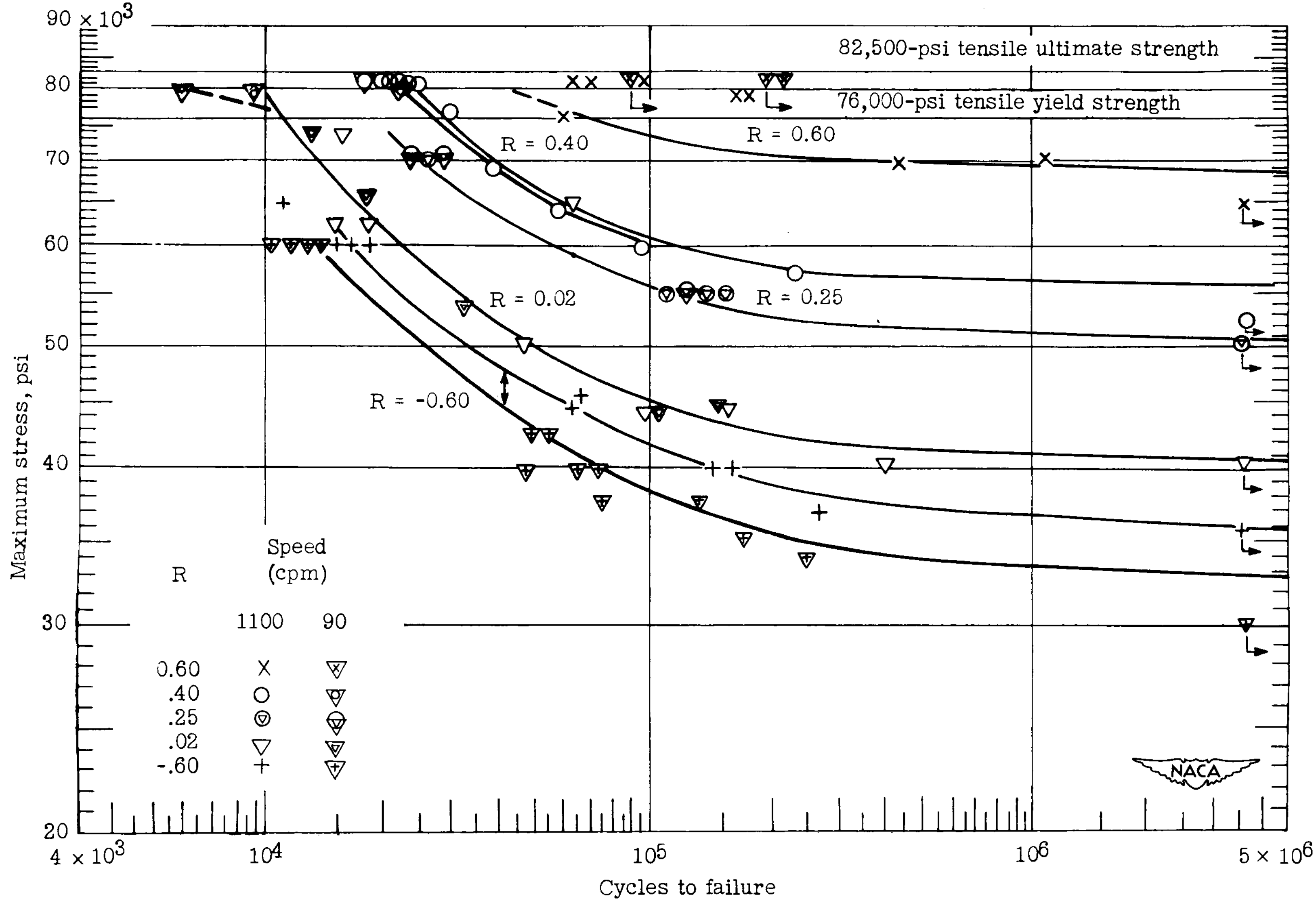

Figure 19.- Results of fatigue tests, at different speeds, on unnotched 75S-T6 aluminum alloy.

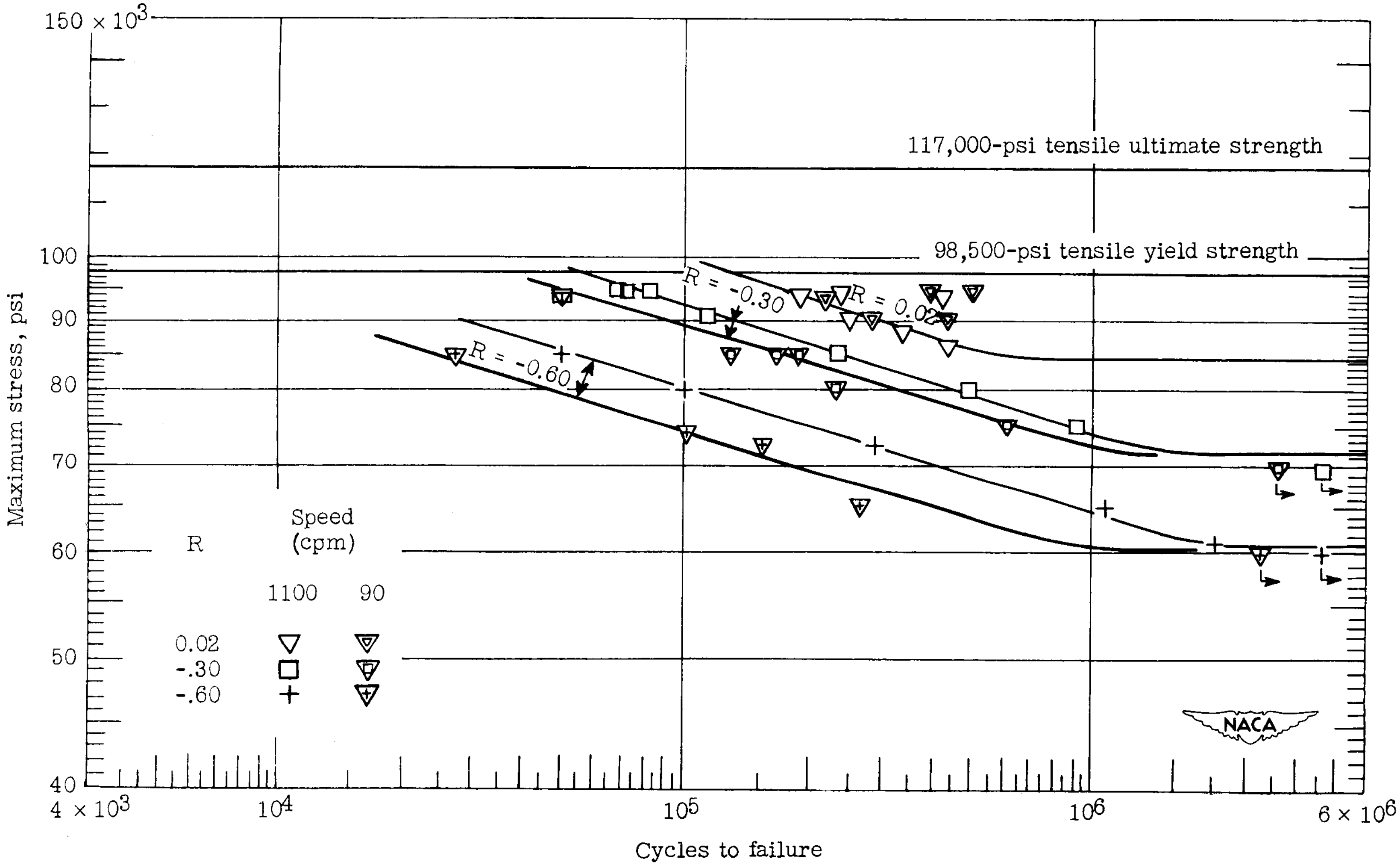

Figure 20.- Results of fatigue tests, at different speeds, on normalized unnotched SAE 4130 steel.

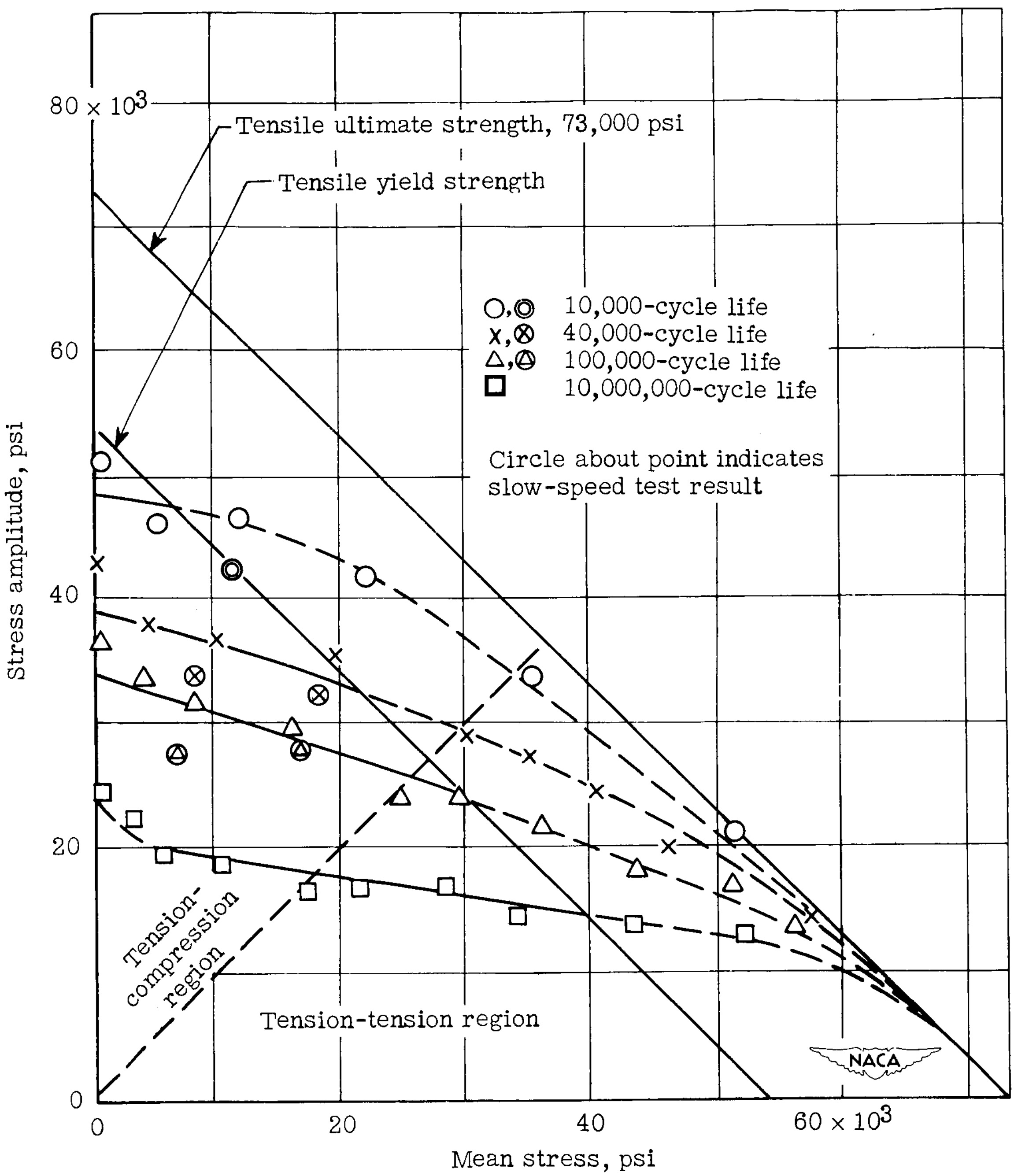

Figure 21.- Constant-lifetime curves, amplitude against mean stress, for 24S-T3 aluminum alloy (see Discussion of Results).

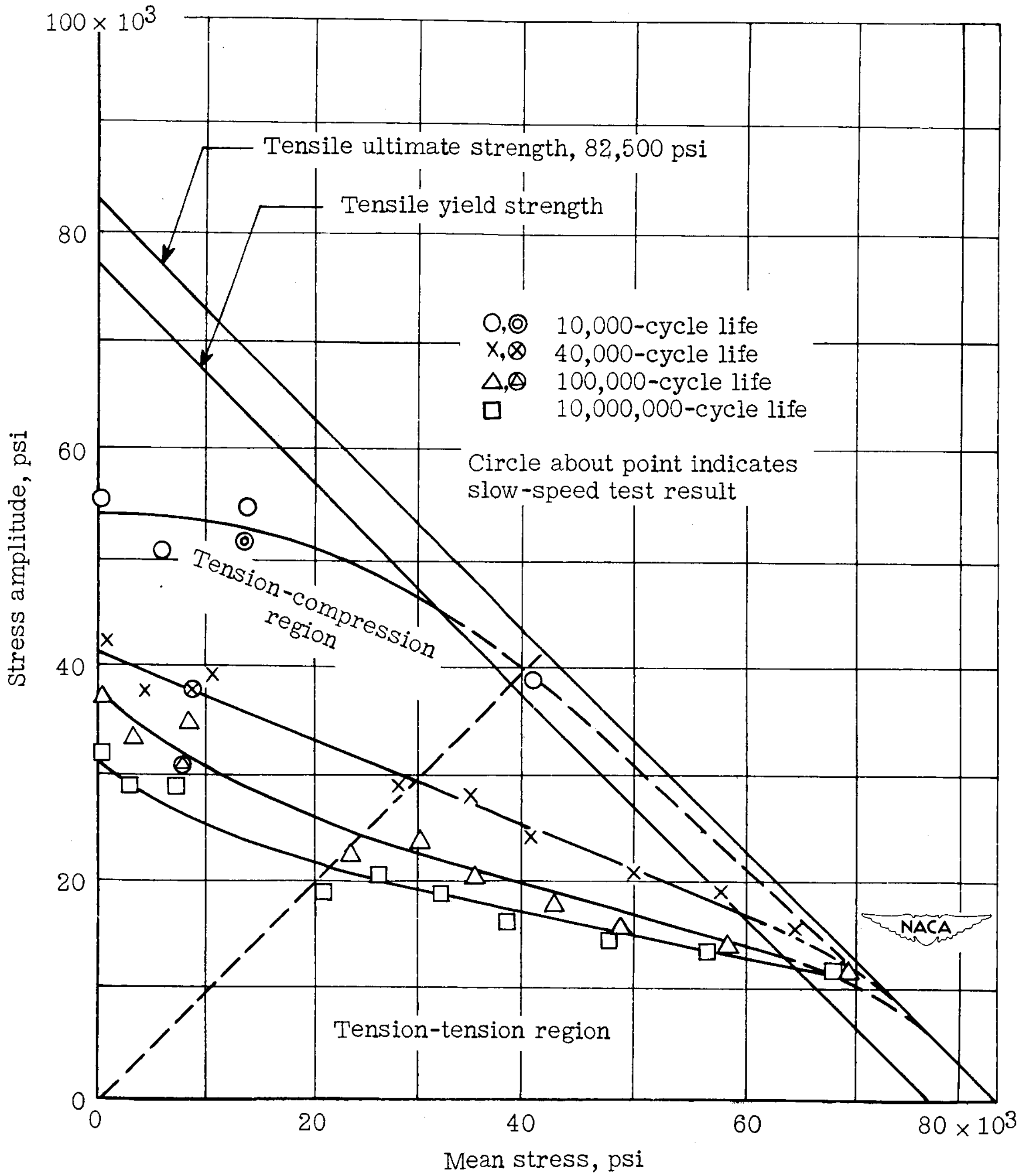

Figure 22.- Constant-lifetime curves, amplitude against mean stress, for 75S-T6 aluminum alloy (see Discussion of Results).

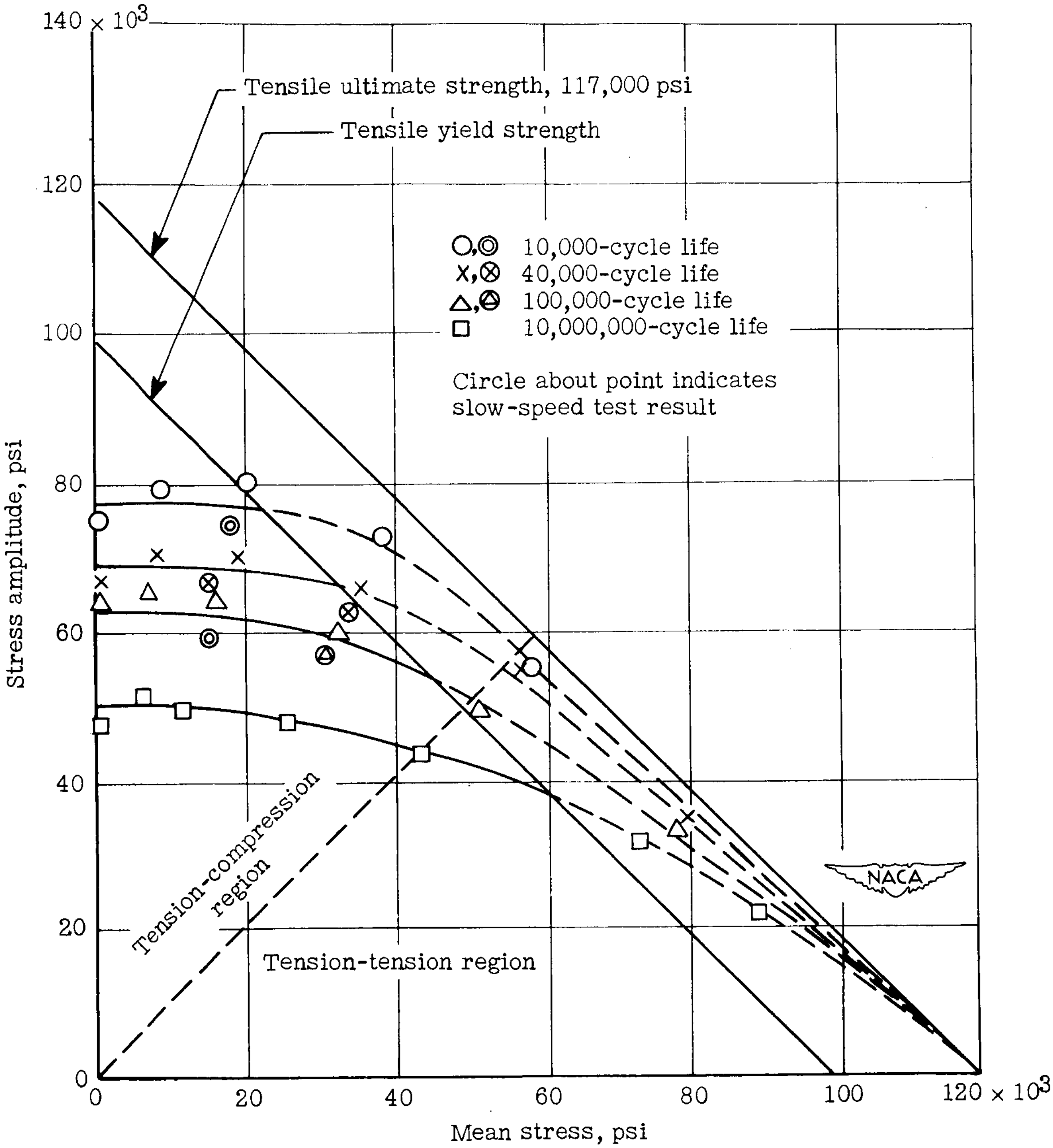

Figure 23.- Constant-lifetime curves, amplitude against mean stress, for normalized SAE 4130 steel (see Discussion of Results).

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